2008

Peatland responses to Holocene climate change in a temperate poor fen, northeastern Pennsylvania

Shanshan Cai
Lehigh University

Cai, Shanshan

Peatland Responses to Holocene Climate Change in a Temperate Poor Fen, Northeastern Pennsylvania

September 2008

PEATLAND RESPONSES TO HOLOCENE CLIMATE CHANGE IN A TEMPERATE POOR FEN, NORTHEASTERN PENNSYLVANIA

by

Shanshan Cai

A Thesis

Presented to the Graduate and Research Committee

of Lehigh University

in Candidacy for the Degree of

Master of Science

in

Department of Earth and Environmental Sciences

Lehigh University

August 2008

Approved and recommended for acceptance as a thesis in partial fulfillment of the requirements for the degree of Master of Science

7-17-08

Date

Dr. Zicheng Yu (Thesis Advisor)

Dr. Robert K. Booth (Committee Member)

Dr. Dork Sahagian (Committee Member)

Dr. Joan M. Ramage (Committee Member)

Dr. Frank J. Pazzaglia (Department Chairperson)

ACKNOWLEDGEMENTS

I wish to thank my supervisor Dr. Zicheng Yu (Zic) for his tremendous patience and guidance throughout this work. Zic has given quite much of his time, energy, and thought to this thesis that I am very grateful. I also wish to thank my advisory committee Dr. Robert K. Booth for his great help on sample collecting and his professional and nice teaching and discussion on testate amoebae and humification analysis, Dr. Dork Sahagian and Dr. Joan M. Ramage for their insights and encouragement.

I wish to extend my sincere thanks to many people who have supported and encouraged me in this work. I thank my colleague Ms. Valerie Sousa for her help on testate amoebae analysis, Ms. Paula Zelanko and Spring 2007 class of EES 396 Wetlands for their help on coring, Mr. Michael Flanagan for his help on humification analysis, and Mr. Cheng Zhao for his help on lab and graph techniques. I thank Fall 2006 class of EES250 Terrestrial Ecosystem for their sharing data with me. I also thank all my graduate colleagues in the Department of Earth and Environmental Sciences for their always kind assistance and encouragement.

The project was supported by a grant to Zicheng Yu from Natural Science Foundation – Carbon and Water in the Earth System program.

Finally, I wish to give my particular thanks to my parents for their support and understanding on my study abroad. This thesis could not have been completed without the tremendous support of my husband, Heng Chiat Tai, throughout my program.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

Abstract

Climate change can significantly affect the carbon balance of peatlands by influencing production and decomposition. Studying boreal peatlands along the edge of their southern limit can provide insight into responses of boreal peatlands to warmer climates. In this study, I derived multi-proxy data through loss-on-ignition, humification, plant macrofossil, pollen, testate amoebae and diatom analysis from Tannersville Bog in northeastern Pennsylvania. The aim was to test the hypothesis that a boreal-type poor fen associated with a temperate climate has a different peat accumulation pattern and higher peat accumulation rate compared to northern continental peatlands.

Plant macrofossil data indicate peat accumulation at Tannersville Bog was initiated by terrestrialization of a glacial lake at ~9000 cal years BP as a rich fen dominated by brown mosses. It changed to a poor fen dominated by Cyperaceae (sedge) and *Sphagnum* at ~1400 cal years BP and to a *Sphagnum*-dominated poor fen at ~200 cal years BP (1750 AD). The association of decline in hemlock (*Tsuga canadensis*) pollen at 5500-3000 years BP with decrease in brown moss macrofossils and increase in fine debris at 5000-2700 years BP appears to support the argument that the hemlock decline in mid-Holocene might have been caused by a dry climate, as documented in other studies. The transition to a poor fen was associated with major changes in lithology and hydrologic conditions, which was probably triggered by a dry climate event documented in a lake-level study in northern New Jersey.

A concave peat-age pattern over the last ~9000 years derived from 8 ^{14}C dates and 240 bulk density measurements is similar to patterns of oceanic bogs but different from those of continental fens. The peat-addition rate of ~170 $gm^{-2}yr^{-1}$ during the last 8000 years with a time-averaged mean of 27 $gCm^{-2}yr^{-1}$ were higher than most boreal peatlands, although deep-peat decomposition rate was similar (0.0004 yr^{-1}). The relatively high accumulation rate may have been caused by high primary production (and possibly low acrotelm decomposition) associated with temperate climate. The results imply that some boreal peatlands can behave as carbon sinks under a warmer and wetter climate in the future.

1 Introduction

Northern peatlands contain a carbon pool of ~455 Gt (1 Gt = 10^{15} g) which is about 30% of the world's terrestrial soil carbon, although they cover only about 2-3% of the earth's land surface (Gorham 1991). Changes of peatlands between carbon source (peat degradation) and carbon sink (peat accumulation) can significantly affect the global carbon cycle especially in response to climate change. Peatlands have originated mostly by the processes of paludification (on previously drier, vegetated mineral soils due to water table rise) and terrestrialization (lake infilling). For example, peat may form directly on fresh, moist, nonvegetated mineral soils exposed from isostatic rebound, and/or be deposited on shallow basins once occupied by early Holocene lakes (Vitt 2006). The term *peatland*, commonly used in the North American literature, is used interchangeably with the European term *mire*.

Variations in climate (temperature and precipitation) have significant impact on carbon dynamics in peatlands through their influences on water table, photosynthesis, decomposition, and CH_4 and CO_2 fluxes. Climatic warming can cause substantial water table drawdown, due to increasing evapotranspiration, and subsequent peat oxidation in northern peatlands (Gorham 1991). However, as most carbon cycling studies have been focused on peatlands in boreal and subarctic regions, such as Canada, Siberia and northern Europe (Ovenden 1990; Gorham 1991; Warner et al. 1993; Charman et al. 1994; Botch et al. 1995; Tolonen and Turunen 1996; Walter 1997; Vitt et al. 2000; Yu et al.

2003; Belyea and Malmer 2004; Belyea and Baird 2006; Frolking et al. 2006; Roulet et al. 2007), responses of peatland carbon dynamics to climatic variations under a warmer climate have been poorly understood.

The research project of this study is focused on the climatic impact on peat accumulation at Tannersville Bog, located in northeastern Pennsylvania. Tannersville Bog is a southerly (41°N) low altitude (277 m above sea level) poor fen dominated by *Sphagnum* moss. This allows to study the impact of Holocene climate change on a boreal-like peatland in a generally warmer climate as a possible analogue of future warm climate, and to evaluate differences in peat accumulation between southern and northern *Sphagnum* peatlands.

1.1 Holocene Climate Change

The Holocene is the present interglacial period, spanning the last 11600 years. The most pronounced radiative changes in the Holocene were a gradual decrease in the summer insolation (June-July-August) of more than 30 W/m^2 accompanied by an increase of about 15 W/m^2 in the winter insolation (December-January-February) (Figure 1a). The seasonal distribution of solar radiation at the top of the atmosphere primarily influences heat distribution on the Earth. The variation of insolation during the Holocene represents half of a 22,000-year precession cycle.

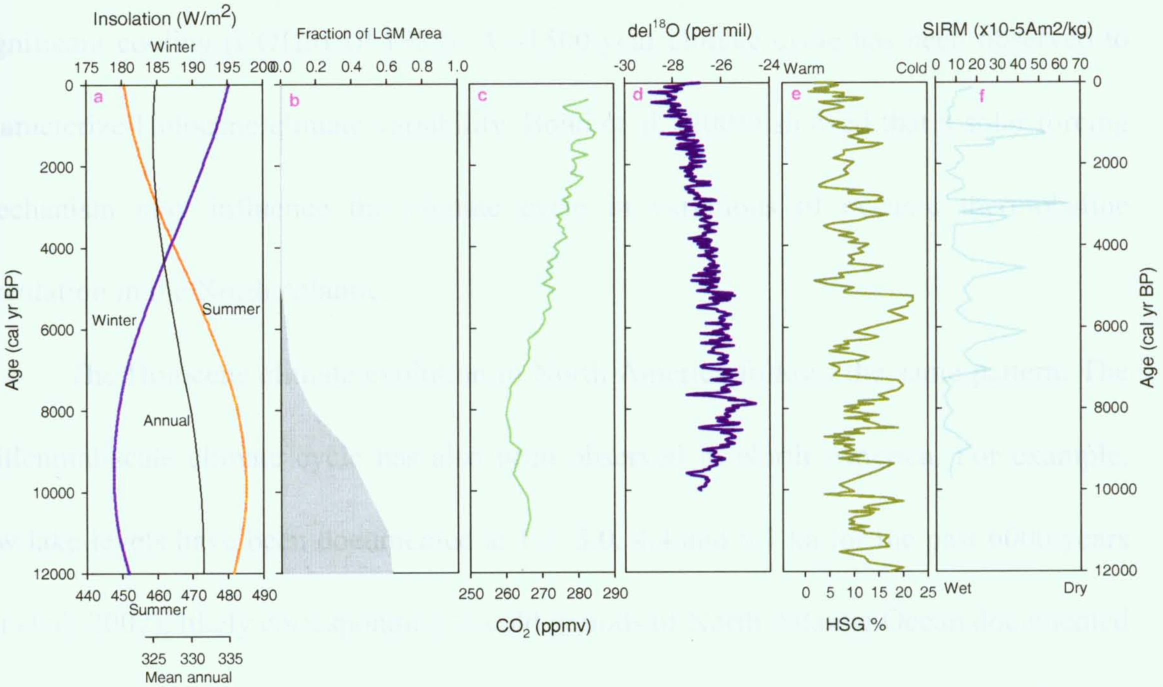

Figure 1 Main boundary conditions and selected climate records for the last 12000 years (the Holocene): a, insolation at 40ºN (summer, winter, and annual) (Berger 1978); b, the area of the Laurentide ice sheet (LIS) as a fraction of its area during the last glacial maximum (LGM) (Shuman and Donnelly 2006); c, atmospheric CO2 concentration from Taylor Dome, Antarctic (Indermuhle et al. 1999); d, $\delta^{18}O$ from Agassiz Ice Cap, Arctic Canada as a proxy of air temperature (Fisher et al. 1995); e, abundance of hematite-stained grains (HSG) from the North Atlantic as a proxy of ice bergs and temperature (Bond et al. 2001); f, SIRM from White Lake, New Jersey, North America as an indicator of lake-level changes (Li et al. 2007).

The Holocene started at 11.6 ka (1 ka = 1000 cal yr BP) associated with a marked climatic warming from 11 to 8 ka (Holocene Thermal Maximum) (Ritchie et al. 1983; Haug et al. 2001). A cold event at ca. 8.2 ka was documented by stable oxygen isotopes from Greenland ice cores (Johnsen et al. 2001). A warming period in the mid-Holocene between 8.6 and 4.3 ka was characterized with 0.5-2°C warmer than today (Fisher et al. 1995; Johnsen et al. 2001). The Little Ice Age started from 0.6-0.5 ka to 0.1 ka with a significant cooling (COHMAP 1988). A ~1500 year climate cycle has been observed to characterize Holocene climate variability. Bond et al. (2001) showed that a solar forcing mechanism may influence the climate cycle in variations of oceanic thermohaline circulation in the North Atlantic.

The Holocene climate evolution in North America follows the same pattern. The millennial-scale climate cycle has also been observed in North America. For example, low lake levels have been documented at 1.3, 3.0, 4.4 and 6.1 ka for the past 6000 years (Li et al. 2007), likely corresponding to cold periods of North Atlantic Ocean documented in Bond et al. (2001). Studies on vegetation history reveal an abrupt decline of *Tsuga canadensis* (eastern hemlock) from 5.5 to 3 ka from pollen records in eastern North America, which may be related to a dry climatic interval that induced regional-to-continental changes in vegetation and water levels during this period (Foster et al. 2006).

1.2 Peatlands and Peatland Carbon Dynamics

Peatland ecosystems can be simply defined as "terrestrial environments where over the long term, on an areal basis, net primary production exceeds organic matter decomposition, leading to the substantial accumulation of a deposit rich in incompletely decomposed organic matter, or peat" (Wieder et al. 2006). Three major types of peatlands are rich fens, poor fens, and bogs (Figure 2). Fens are peatlands characterized by the presence of surface and ground water which also transports nutrients to peatlands (Vitt

2006). Rich fens are often dominated by true mosses (i.e. brown mosses) and sedges, with high amounts of base cations and alkalinity, high pH, and high nutrient availability. Poor fens are often dominated by peat mosses (i.e. *Sphagnum*), low base cations and little or no alkalinity, low pH, and low nutrient availability. Bogs, especially raised bogs, are peatlands with precipitation as the only source of nutrient and water, and are typically characterized by abundant *Sphagnum* species, decreased amounts of base cations and no alkalinity, increased acidity, and decreased nutrient availability (oligotrophy).

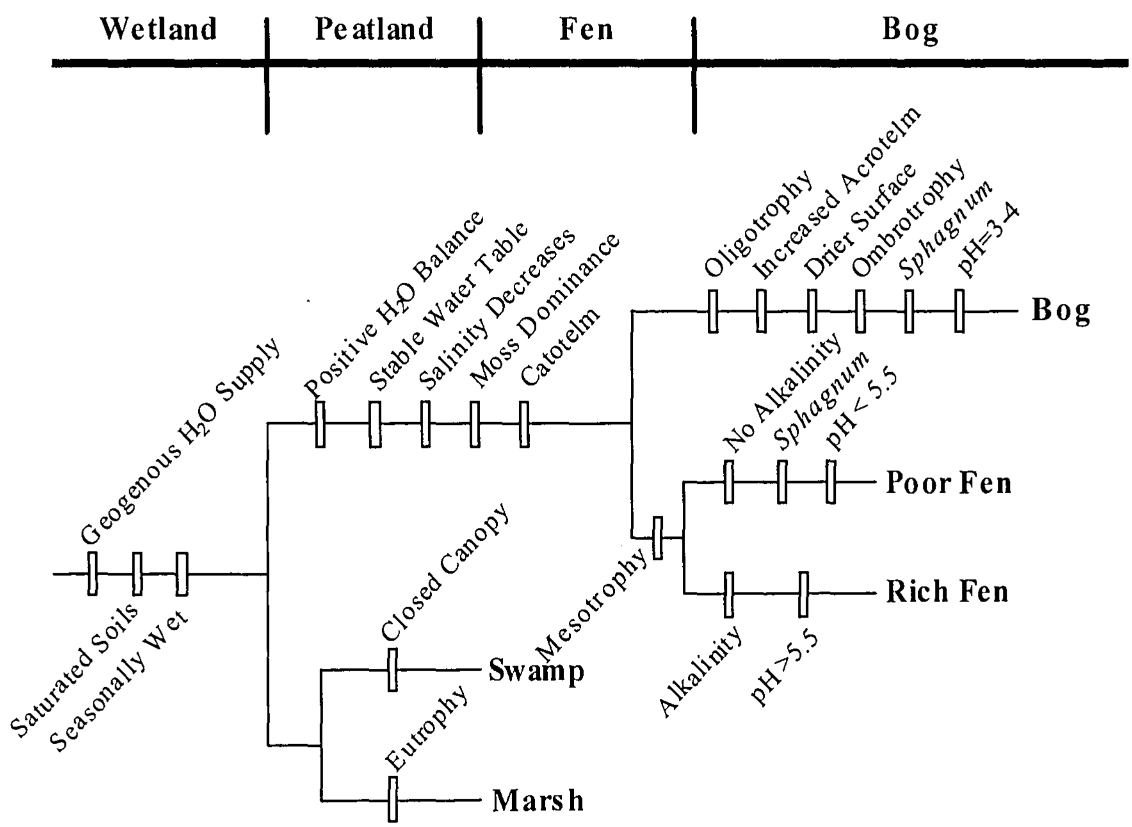

Figure 2 Classification of functional levels of ecosystem (top) and criteria (bars with hierarchy clusters) that define the major boreal wetland types. Modified from Vitt (2006).

Peat accumulates whenever the rate of organic matter production exceeds the rate of decay. Though net primary production in boreal peatlands is lower than in many other ecosystems, peat accumulates as decay rates are extremely low in peatlands due to water-logged environment and anoxic conditions (Gorham 1991). The peat accumulation rate varies among peatlands owing to differences in geographical location (south greater than north), age (young greater than old), and type (Vasander and Kettunen 2006).

The peat growth rate in peatlands is in some degree regulated by *Sphagnum* moss which is the most dominant species in bogs and poor fens (Rydin et al. 2006). The refractory nature of *Sphagnum* causes the high acidity of soil and low decomposition of *Sphagnum* litter in the soil (e.g., decay rate of *Sphagnum* is 1/4 of that in other plants) (van Breemen 1995). *Sphagnum* peat conducts heat poorly, causing a short growing season for vascular plants on boreal peat, whereas the shallow euphotic zone of the *Sphagnum* carpet tends to be relatively warm (van Breemen 1995). The presence of *Sphagnum* also reduces supply of nutrients to vascular plants by effective interception of nutrients from the atmosphere and by slow mineralization and recycling (Maimer et al. 1994). Finally, depressed growth of vascular plants increases light availability and moisture by decreased evapotranspiration, which reinforces *Sphagnum* growth, and therefore peat growth. By building peat out of its own dead tissue, *Sphagnum* moss changes the supply of resources to other plants as the ecosystem engineer in bogs and poor fens (Rydin and Jeglum 2006).

1.3 Conceptual Models of Peat Accumulation

Dynamics of peat accumulation are determined by the processes of production and decay of organic matter. Based on different functional behaviors of production and decay, two or three layers can be distinguished in peat forming systems: litter, acrotelm, and catotelm (Clymo 1984; Yu et al. 2001a; Belyea and Baird 2006). In the litter layer, or living plants layer, production is the major process of carbon input, while rapid initial decomposition removes about 20% of the litter mass including leaching of soluble organic materials (Heal et al. 1978), before the litter enters the underlying layer as a new source of peat. The product of this initial decay is most likely in the form of dissolved organic carbon rather than CO_2 or CH_4, and the decomposition rates of litter are influenced by mean temperatures and temperature fluctuations (Clymo 1984; Yu et al. 2001b). Below the litter layer is the acrotelm, which is a layer with fluctuating water table, variable water content, periodically aerobic, high decomposition rate with both aerobic and anaerobic bacteria, and relatively fast water movement. Catotelm is the layer permanently saturated with water, and therefore only comprises low anaerobic decomposition. The boundary between the acrotelm and catotelm is approximately the average water table below the vegetated surface (Ingram 1983; Clymo 1984). The bulk density becomes higher when plant mass decay and collapse, so the hydraulic conductivity is much lower in the catotelm than in the acrotelm.

Peat accumulation in the catotelm can have three general trajectories as shown in the age-depth (cumulative mass) plots: linear, concave, and convex patterns (Figure 3). A linear relationship (Figure 3: curve II) between cumulative peat mass and time could occur if change in mass over time were constant (constant apparent accumulation rates). This assumption seems implausible in most peatlands, and the generally accepted assumptions are that the rate of decay is directly proportional to the amount of mass left (Jenny et al. 1949; Clymo 1984). Two other trajectories have been observed in various peatland types. The concave curve (Figure 3: curve I) developed by Clymo (1984) for cumulative mass vs. age indicates higher apparent accumulation rates in younger peat and lower rates in older peat, which is the general pattern of peat accumulation in bogs under oceanic climate. The convex curve (Figure 3: curve III) developed by Yu et al (2003) has been observed in continental fens in western Canada, which implies lower apparent accumulation rates in younger peat and higher rates in older peat. The convex shaped pattern implies that peatlands will reach their growth limit sooner and that their carbon sequestration capacity will decline faster than would be expected in the concave shaped pattern (Figure 3), disregarding climatic change (Yu et al. 2003).

Climatic change (variations in temperature and precipitation) and induced changes in moisture and vegetation would have significant effects on the rate of peat decay, the rate of peat addition into the catotelm (the mass input from the bottom of acrotelm per unit time), and therefore the peat accumulation pattern. Based on the concave model, Clymo (1998) suggested that the value of rate of peat addition was related to the degree-days above 0° C and proportional decay rate was exponentially related to mean annual temperature. The ranges of average long-term carbon accumulation (g C m^{-2} yr^{-1}) estimated in individual cores from Finnish peatlands were much higher in bogs than in fens and almost double in southern peatlands as compared with those in the northern Boreal zone (Tolonen and Turunen 1996).

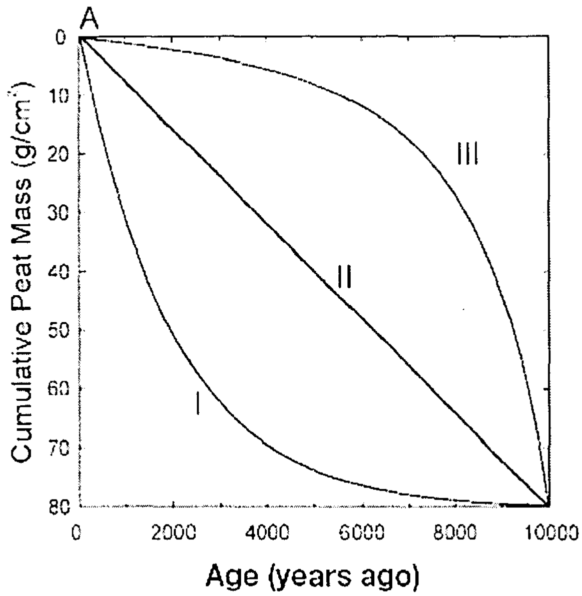

Figure 3 Generalized trajectories of the long term carbon accumulation in peatlands: I: higher apparent accumulation rates in younger peat and lower rates in older peat (concave pattern); II: constant apparent accumulation rates; and III: lower apparent accumulation rates in younger peat and higher rates in older peat (convex pattern). Modified from Yu (2006).

1.4 Research Objectives and Questions

Peat accumulates whenever the rate of organic matter production exceeds the rate of decay. Higher peat accumulation rates can be attributed to two reasons: higher production at the peat surface, or a lower decomposition rate. Warmer climate with a longer growing season and/or higher moisture conditions can favor primary production in peatlands (Belyea and Malmer 2004). A longer growing season and/or higher temperature may result in greater evaporation and a longer seasonal drawdown of water table, which exposes more peat to be oxidized; meanwhile, the decomposition rate is positively correlated with soil temperature (the higher the soil temperature, the higher the decomposition rate) (Carroll and Crill 1997; Frolking et al. 2001). Conversely, wetter climate or higher precipitation would affect the dynamics of hydrology in peat, likely increasing primary productivity and water table which impedes decomposition of peat.

The aim of this research is to test the hypothesis that a boreal-type poor fen associated with a temperate climate, such as Tannersville Bog, has a different peat accumulation pattern and higher peat accumulation rate during the Holocene compared to northern continental peatlands. The temperate climate is characterized by warm climate with an average high temperature of about 10°C and annual precipitation great than 1000 mm, while the climate of northern continental peatlands is characterized by a mean annual temperature of 0°C and annual precipitation less than 600 mm. Climate, therefore, must have a significant effect on carbon accumulation by influencing primary production and decomposition. To evaluate this idea, I will address the following questions:

1) What is the peat accumulation pattern of Tannersville Bog during the Holocene? Is this pattern different from the pattern observed in northern continental peatlands of different types in boreal and subarctic regions? What is the reason for the difference?

2) What is the peat accumulation rate at Tannersville Bog? Is the rate higher or lower than the rates of northern peatlands of different types? What caused the higher/lower rates compared to the rates of northern peatlands?

3) How have the local vegetation, substrate moisture conditions and regional vegetation changed at Tannersville Bog during the Holocene? Were the changes in local vegetation succession influenced by climate change?

4) How has peat accumulation of Tannersville Bog responded to the variations of local vegetation, substrate moisture condition and regional vegetation during the Holocene?

1.5 Research Approach

I used multi-proxy data derived from peat cores to document the peat accumulation pattern and accumulation rate, climate variations, and decomposition at Tannersville Bog. Proposed analyses are illustrated in a flow chart (Figure 4). Loss-on-ignition (LOI) analysis was used to estimate organic matter content, to calculate bulk density, and to quantify the accumulation of organic matter. AMS radiocarbon dating was used to derive chronology and to calculate peat accumulation rates during the Holocene. A simple conceptual model was used to estimate long-term peat-addition rate (PAR) and decomposition coefficients by curve fitting analysis. Humification and C/N ratio analyses were conducted to examine the variations of the degree of decomposition and the carbon loss along the peat profile, which would help me to understand the relative roles of production and decomposition processes in determining peat accumulation.

These results will be compared with data from Alaskan peatlands and other northern peatlands to investigate the differences between temperate and boreal peatlands, and to understand the effects of warmer climate on peat accumulation at Tannersville Bog.

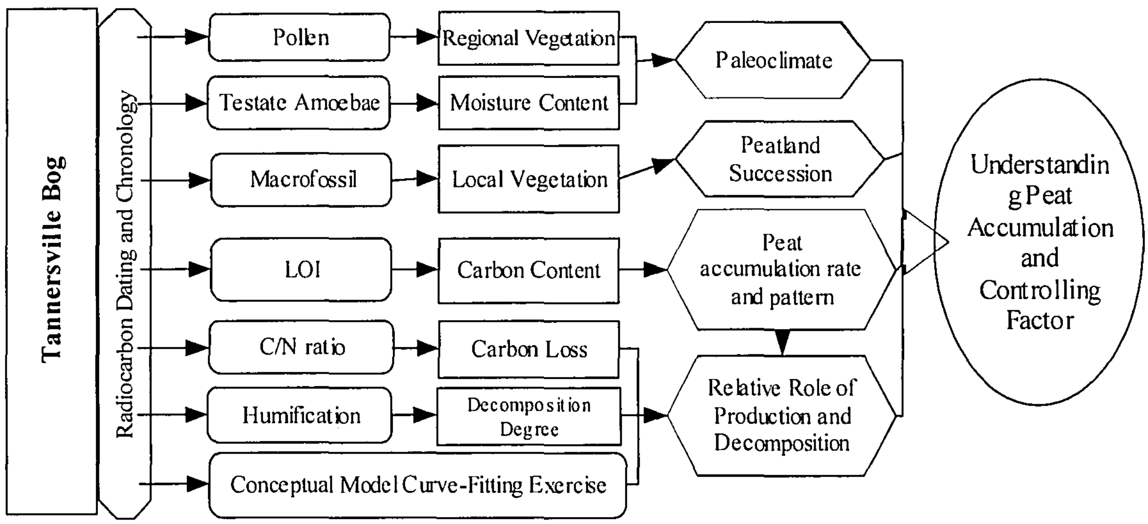

Figure 4 Flow chart and research design for the study at Tannersville Bog.

Climate change and variability can be inferred from regional vegetation, local vegetation and moisture conditions at Tannersville Bog. Pollen analysis was conducted to reconstruct regional vegetation, and macrofossil analysis was utilized to reconstruct local vegetation. Testate amoebae analysis was conducted to reconstruct surface moisture condition. The reconstructed paleoclimate was used to study the impact of climatic variability on local vegetation change and peat accumulation.

2 Study Region and Study Site

2.1 Physiography

Tannersville Bog is located at the edge of the Pocono Mountains in Monroe County, Pennsylvania (75° 16'W, 41° 02'N, Figure 5) with a current size of the 3 km^2. Bedrock in the region consists of gently dipping Paleozoic age (570-225 million years, or ma) strata consisting of sandstones and shales. During the Pleistocene (1.8 ma - 10 ka) the rocks were eroded by advancing glaciers and covered by glacial deposits (Hirsch 1977). Tannersville Bog was once a glacial lake before the Holocene and developed by the lake-infilling (terrestralization) process (Watts 1979).

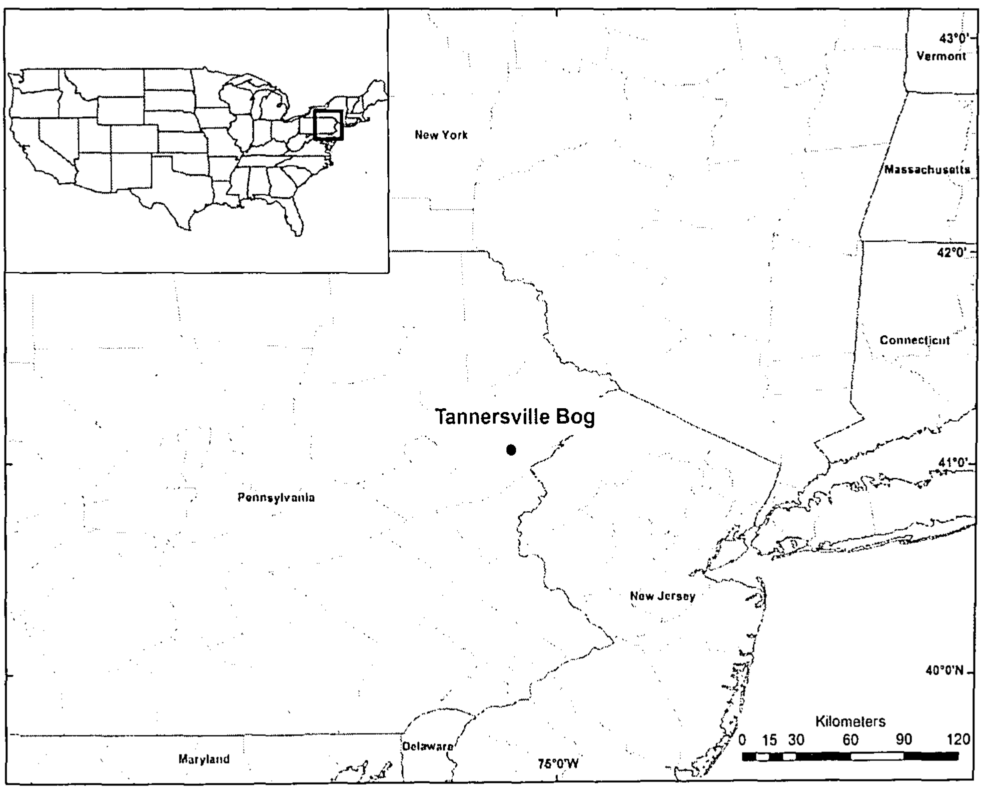

Figure 5 The location map of Tannersville Bog, Pennsylvania.

2.1 Physiography

Tannersville Bog is located at the edge of the Pocono Mountains in Monroe County, Pennsylvania (75° 16'W, 41° 02'N, Figure 5) with a current size of the 3 km^2. Bedrock in the region consists of gently dipping Paleozoic age (570-225 million years, or ma) strata consisting of sandstones and shales. During the Pleistocene (1.8 ma - 10 ka) the rocks were eroded by advancing glaciers and covered by glacial deposits (Hirsch 1977). Tannersville Bog was once a glacial lake before the Holocene and developed by the lake-infilling (terrestralization) process (Watts 1979).

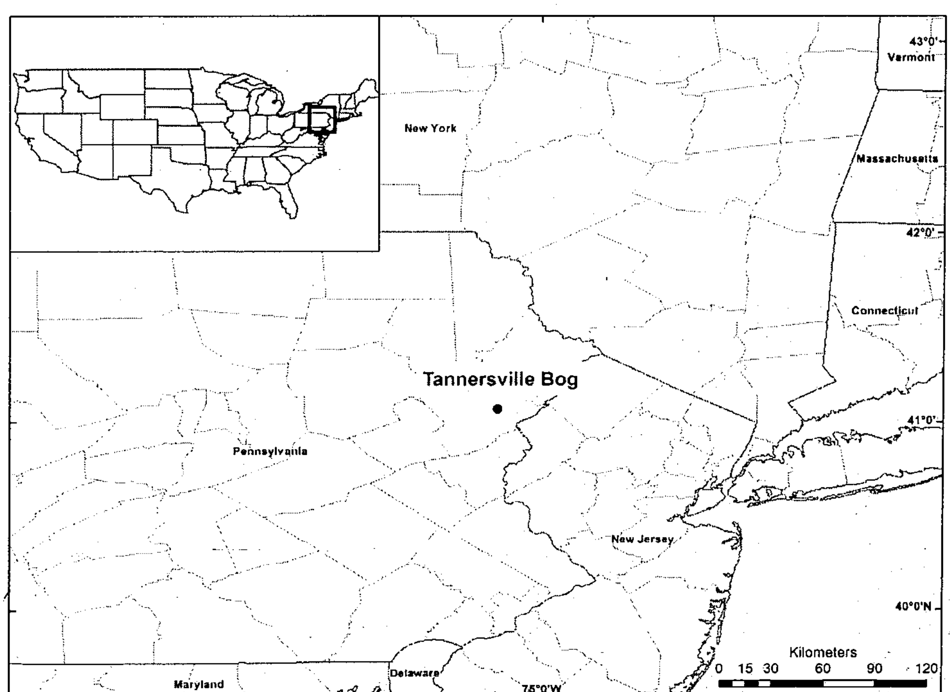

Figure 5 The location map of Tannersville Bog, Pennsylvania.

2.2 Climatology

The study area is characterized by temperate climate with a mean maximum air temperature of 16°C, a mean minimum air temperature of 3°C, and a mean annual temperature of ~10°C (Stroudsburg station 2005 NOAA, 10 km from Tannersville Bog). The mean annual precipitation is around 1256 mm (Stroudsburg station 2005 NOAA). In 2006, 1570 mm of precipitation was reported at Tannersville station (Tannersville 2e, NOAA). Figure 6 shows the monthly average air temperature and precipitation in the study area based on the normal climate from 1971 to 2000.

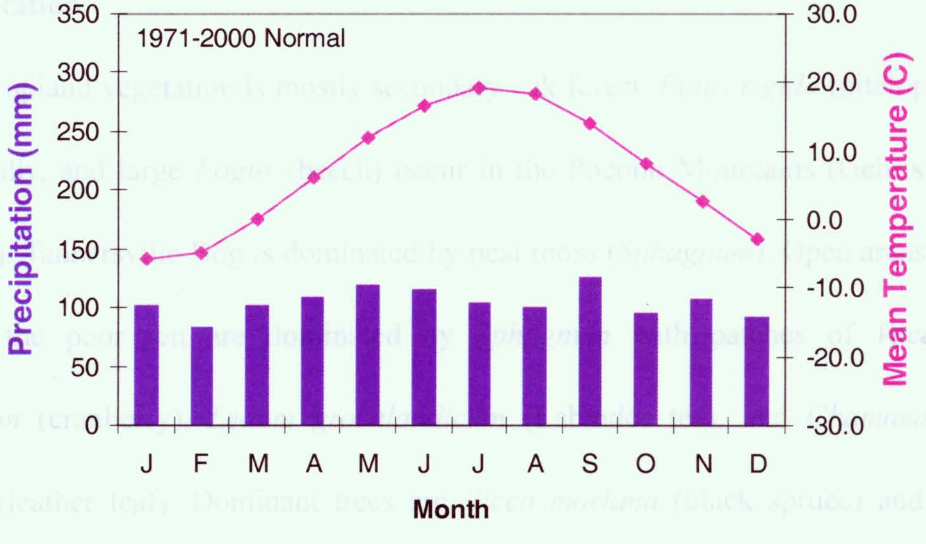

Figure 6 Climate Normal (1971-2000) of monthly average air temperature (line with markers) and precipitation (bars) of the study area (Data from the weather station of Tobyhanna Pocono Mountain which is 11 km northwest of Tannersville Bog).

2.3 Hydrology

Tannersville Bog is fed mainly through precipitation and surface water (Luebbe 2007). Although it is called a bog, it is actually an acidic poor fen also fed by groundwater coming from the uplands, with a pH of ~5.1. A first-order stream, Cranberry Creek, flows through Tannersville Bog. The discharge and flux of dissolved organic carbon (DOC) in Cranberry Creek are greatest from the summer into early-fall and generally varied with average temperature (Luebbe 2007). In 2006, the DOC concentration ranged from 3 to 23 mg/L in Cranberry Creek with an annual DOC flux of 12.18 g/m^2/yr (Luebbe 2007).

2.4 Vegetation

The upland vegetation is mostly secondary oak forest. *Pinus rigida* (pitch pine) is present locally, and large *Fagus* (beech) occur in the Pocono Mountains (Gehris 1964; Watts 1979). Tannersville Bog is dominated by peat moss (*Sphagnum*). Open areas in the middle of the poor fen are dominated by *Sphagnum* with patches of *Vaccinium macrocarpon* (cranberry), *Ledum groenlandicum* (Labrador tea), and *Chamaedaphne calyculata* (leather leaf). Dominant trees are *Picea mariana* (black spruce) and *Larix laricina* (tamarack) rooted in hummocks of *Sphagnum* moss. Tannersville Bog is one of the southern-most (41°N) low altitude (277 m) *Sphagnum* dominated poor fens along the eastern seaboard, and one of the Nature Conservancy's first preserves.

2.5 Site History

Tannersville Bog was first investigated by Gehris (1964), who analyzed pollen grains from a 10.5-m peat profile from a site close to the creek, in the central open area of the peatland which was believed to be deepest (Figure 7). He noted two watery pockets at 1.5-1.8 m and at 5.8-6.1 m below the peat surface, attributed to floating mats. Above 1.5 m, the peat was relatively coarse and dark brown in color. From 1.8 to 8.1 m, it was peaty brown (except for watery pocket). From 8.1 to 10.2 m, the gritty content of peat gradually increased. Below 10.2 meters, the sediment is bluish-gray clay having a unique purplish tint in the sunlight. In the report to the Nature Conservancy, Hirsch (1977) indicated (Figure 7) that the peat is deepest at the central part of the bedrock valley with a maximum depth of ~11 m; the peat is underlain by a dark brown peaty clay that ranges in thickness from 0 to 5.5 m wherever the peat is more than 3 m; beneath the peat, the basal sediment is a layer of pink, gray, or white silty clay (>0.6 m thick) extending over the top of bedrock that forms an impermeable layer between the bedrock and overlying peat where the depth is over 6 m.

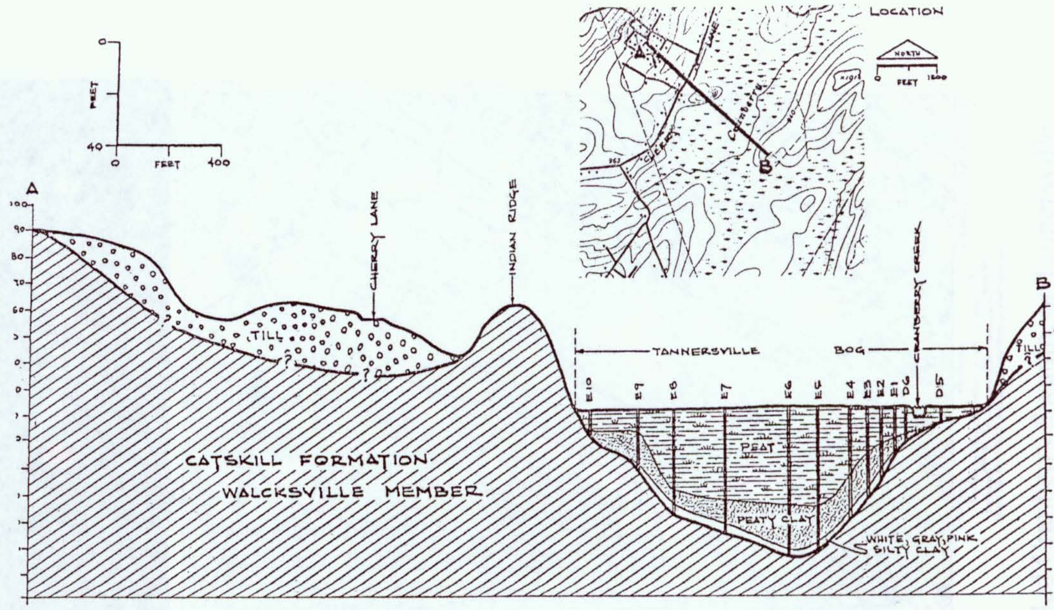

Figure 7 Cross-section of the Cranberry Creek Valley. The Tannersville Bog section is based on borings that were proximal to the line of section (Hirsch 1977).

Watts (1979) analyzed pollen and macrofossils from a 13-m sedimentary core from Tannersville Bog (Figure 8) spanning 13,300 ^{14}C years to investigate the earliest vegetation after deglaciation. He calculated an average sedimentation rate of 12.2 yr/cm which did not distinguish the sedimentation of peat and lake sediments. Watts' (1979) pollen diagram illustrated the decline of white pine and a rise in oak that is accompanied by a steep rise in hemlock shortly after 9800 ^{14}C yr BP; oak has been continuously predominant through the Holocene to the present day while hemlock declined before 4600 ^{14}C yr BP. *Sphagnum* spores and aquatic taxa were present throughout the Holocene but became dominant in the late Holocene. Macrofossil results suggest that Tannersville Bog was a lake until the middle Holocene when *Larix* appeared in the profile after 8000 ^{14}C yr BP.

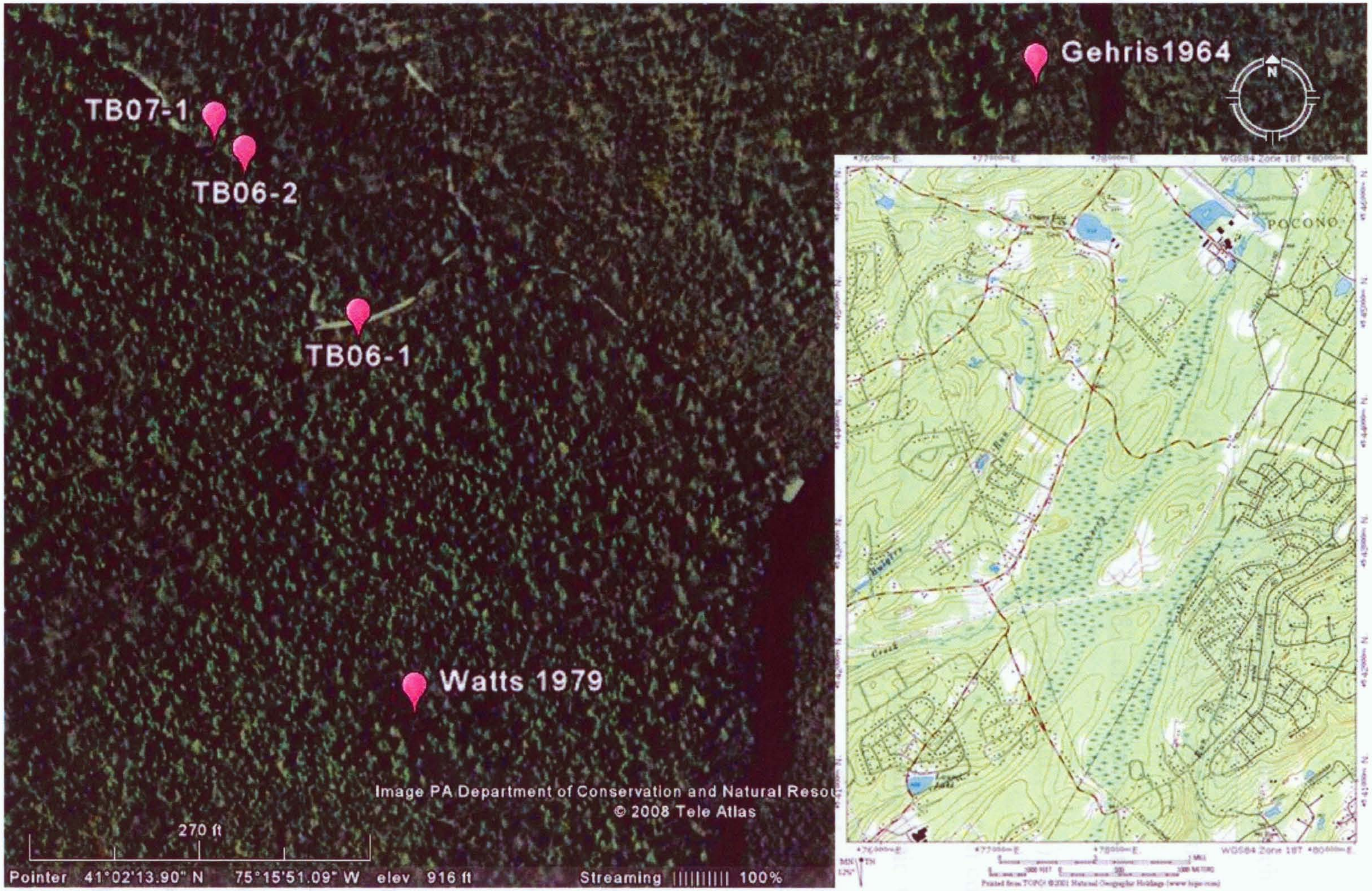

Figure 8 Topographic map and Google image of Tannersville Bog (also called Cranberry Swamp, or Tannersville Cranberry Bog), with previous coring sites and our three coring sites (solid dots). Light-colored linear features are boardwalk.

3 Methods

3.1 Sample Collecting

A 1073-cm sediment core (TB07-1) was collected on 24 March 2007 at Tannersville Bog (41.03817° N, 75.26582°W), about 10 meters away from boardwalk west of the Cranberry Creek (Figure 8). The top 183 cm were recovered using a 10.2-cm-diameter modified Livingstone piston corer (Wright et al. 1984), and lower sediments were collected using a 5-cm-diameter modified Livingstone piston corer. Core segments of 100 cm long were extruded in the field and wrapped in plastic wrap and stored in polyvinylchloride pipe during transportation to the laboratory, where they were stored at 4°C in a cold room.

3.2 Radiocarbon Dating

AMS radiocarbon analysis on hand-picked plant macrofossils was used to date the peat core. Only the macrofossils from non-aquatic plants (e.g., *Sphagnum* moss, Ericaceae leaves, charcoal, or ligneous plant fragments) are used for dating to avoid hard-water effect (some aquatic plants absorb bicarbonate formed from limestone). AMS samples were analyzed at the W. M. Keck Carbon Cycle Accelerator Mass Spectrometry Laboratory (KCCAMS) in the Department of Earth System Science at the University of California, Irvine. Thirteen peat samples from selected 1-cm-thick slices at approximately 100-cm intervals were submitted for AMS radiocarbon dating, of which 12 radiocarbon dates were obtained. Radiocarbon dates were calibrated with IntCal04 calibration data set

(Reimer et al. 2004) using the program Calib v5.01 (Stuiver et al. 1998). Age-depth model was reconstructed with a cubic polynomial regression on the median probability age within ~95% possibility range (2 standard deviation).

3.3 Loss on Ignition Analysis

Sequential loss on ignition (LOI) analysis is a commonly used method to estimate the moisture, organic and carbonate contents of sediments (Dean 1974; Heiri et al. 2001). Moisture content is estimated by the weight loss at 100°C; organic matter content can be calculated by the weight loss at 550°C; and carbonate content is calculated by the weight loss at 1000 °C. LOI provides a fast and inexpensive method of determining organic content and carbonate of clay-poor calcareous sediments with precision and accuracy (Dean 1974). Volumetric samples (1.4 cm^3) were selected from 1-cm-thick slices at 2-cm interval for the upper 4-m peat core and at 10-cm interval for the lower 6.73-m peat core from Tannersville Bog. Bulk density measurements were calculated using sample volume and dry weight.

3.4 Humification and C/N Analysis

Humic acids are produced by the decomposition of organic material. They are dark brown in solution. The proportion of humic acid increases as peat decomposes. This principle has been used to estimate the quantities of humic acid in peat, based on the assumption that the color of the extracts are indicative of the degree of humification and therefore the degree of decomposition (Caseldine et al. 2000). Since decomposition is primarily a function of the degree of surface wetness of a peatland, the humification record represents a paleohydrological proxy, although it is influenced by the botanical composition of the peat. The sodium hydroxide (NaOH) extracts are most widely used in this technique. The standard colorimetric technique has been used to reconstruct peatland surface wetness in several recent studies (Booth and Jackson 2003; Langdon and Barber 2005).

Fossil C/N ratios of bulk peat and *Sphagnum* fossils provide an index to represent the degree of carbon losses through anaerobic decay in the catotelm (Kuhry and Vitt 1996). Slow anaerobic decomposition in the catotelm results in continuous carbon loss through processes such as sulphate reduction and methanogenesis (Mitsch and Gosselink 2000). Nitrogen is lost mainly by becoming immobilized in the catotelm in spite of the small amount lost from the acrotelm through denitrification, grazing, burning, surficial runoff, and erosion (Mitsch and Gosselink 2000). About 95-98% of the nitrogen in the moss and other components of the peat is recycled while 80-90% of the carbon is lost through aerobic decomposition (Kuhry and Vitt 1996). Due to the preferential loss of carbon in the catotelm, nitrogen is consequently relatively enriched and carbon/nitrogen ratios gradually decrease moving down along the peat profile (Malmer and Holm 1984; Kuhry and Vitt 1996). Study on fossil C/N ratios by Kuhry and Vitt (1996) shows that the decrease of C/N ratios corresponds to carbon loss when nitrogen losses in the catotelm of bog ecosystems can be considered negligible, and that net carbon accumulation rates are significantly correlated with the nitrogen accumulation rate gradient.

Humification and C/N analysis were conducted on peat samples from Tannersville Bog. A Genesys™ 10 series spectrophotometer (Thermo Electron Corporation) was used to measure the percentage of light transmittance at wavelengths of 400-1000 nm. Measurement was conducted on 0.2 g powdered peat from 1-cm-thick slices at 10-cm sampling interval. The percentage of light transmittance at 540 nm was used in the paleo-hydrology reconstruction. The higher percent of transmittance means lower degree of peat decomposition, indicating a wet condition (Booth and Jackson 2003). C/N ratio measurements for the short core were obtained by measuring carbon and nitrogen content in samples at the same resolution with humification analysis, using total organic carbon and nitrogen analyzer (Shimadzu TOC-Vcph and TNM-1).

3.5 Plant Macrofossil Analysis

Plant macrofossils preserved in peat profiles are indicative of local vegetation changes (Barber et al. 1994). Variations of local vegetation could represent a sequence of autogenic change or could be in response to climate change (allogenic effect). I used a semi-quantitative method for macrofossil analysis following Yu et al. (2003). Peat subsamples of approximately 1 cm^3 were taken every other centimeter for the upper 4-m section and every 20-cm for the lower 6.73-m section and dispersed into a custom-designed picking tray with channels ("channeled plexiglass template") without chemical treatment and sieving. The macroscopic components are usually composed by recognizable plant remains and unrecognizable debris (Yu et al. 2003). The relative abundance of unrecognizable debris independently reflects the degree of decomposition of each measured sample. The subsamples were examined under a dissecting stereomicroscope to identify and estimate relative abundance of different macroscopic components, including *Sphagnum,* brown mosses, herbs (Cyperaceae), ligneous (woody materials from shrubs or trees and charcoals), and unrecognizable debris. Identification was aided by Lévesque et al. (1988) and online identification key by Dale Vitt (http://www.peatnet.siu.edu/PeatGuide.html). The sampling resolution of plant macrofossil analysis is the same as for LOI analysis.

3.6 Pollen Analysis

Pollen as a proxy of regional vegetation and climate change at Tannersville Bog allow me to address the possible connection between climate, upland vegetation, and peatland ecosystem changes. The hemlock (*Tsuga*) decline at ~5.5 ka is a widespread palynological event in eastern North America and has been attributed to a dry climate (Yu et al. 1997; Foster et al. 2006). To study the peatland responses to this event, the pollen record provides the information of climate change that is used to investigate the association with other independent records, such as plant macrofossil-inferred peatland vegetation dynamic and testate amoeba-inferred water table depth. Also, in northeastern United States *Ambrosia* (Ragweed) pollen increased rapidly, corresponding to the European settlement and forest clearance for agriculture at ~250 years BP (Russell 1980;

Willard et al. 2003). This pollen horizon can be used for dating the recent peat profile.

Pollen analysis was conducted on 1-cm-thick slices from Tannersville Bog at 10-cm interval for the upper 3.4-m by using the same sample preparation for testate amoebae analysis as described in the following section. The lower 7.3-m peat was analyzed at 20 cm intervals with a modified standard method for pollen sample preparation (Fægri and Iversen 1989). One *Lycopodium* spore tablet (batch No. 938934, mean = 10679 spores) was added during sample preparation as spike used in the calculation of pollen concentration. Pollen and spores were identified and counted under a compound microscope at 400× magnification following the illustrated key by McAndrews et al. (1973). The percentages of pollen, spore and aquatics were calculated based on the total pollen sum which includes trees and shrubs, upland herbs, Pteridophytes, unknowns and indeterminable types. The pollen diagram was plotted using TGView v 2.0.2 with cluster analysis conducted by CONISS (Grimm 1987).

3.7 Testate Amoebae Analysis

Testate amoebae (Protozoa: Rhizopoda) assemblages provide quantitative estimates of water table and soil moisture in *Sphagnum* peatlands (Woodland et al. 1998; Charman et al. 1999; Booth 2002; Booth and Jackson 2003; Charman et al. 2004). Testate amoebae are microscopic Protists, typically between 20 and 250 μm in size, which inhabit the surface layers of peatlands and other moist soils and the benthic environment of freshwater lakes (Charman et al. 2000). Testate amoebae live within thin water films around soil particles and on *Sphagnum* leaves and stems. In *Sphagnum* peatlands, testate amoebae are a major component of the microfauna (Woodland et al. 1998). The sensitivity of testate amoebae to moisture has been documented in several paleoecological studies by comparison with other independent proxies, including peat humification and plant macrofossils (Charman et al. 1999; Booth and Jackson 2003; Langdon and Barber 2005). Charman (2004) examined the relationships between a 200-year record of reconstructed water table change from testate amoebae, instrumental water table and climate data in Europe, and showed that ombrotrophic peatland surface wetness records primarily reflected summer moisture balance.

At Tannersville Bog testate amoebae analysis was carried out at 10-cm intervals using 3 cm^3 of peat samples from selected 1-cm-thick slices using the method described in Booth (2007). Taxonomy follows Charman et al. (2000) and Booth (2007). A *Lycopodium* spore tablet was added to each sample for the calculation of testate amoeba concentration. The count total is the sum of all identified testate amoeba types and indeterminables. The testate amoebae diagram was plotted in TGView v 2.0.2 with CONISS for zonation. Water-table depths were reconstructed by weighted averaging partial least squares transfer function model based on a calibration datasets developed from North American peatland samples (Booth 2008).

3.8 Diatom Analysis

Diatoms represent a group of algae whose siliceous valves are usually well preserved in sedimentary deposits. They are usually typical of clean-water environments (Cushing and Allan 2001). Diatom growth is optimal in open water and in low acidity environments, so its abundance indicates the moisture conditions and types of peatlands (Smol 1990). I estimated the abundance of diatoms on pollen and testate amoebae slides for the samples from the upper 340-cm section of core TB07-1, without identifying to specific taxa. The calculation of diatom concentration is based on the same spike as described in section 3.7.

3.9 Peat Accumulation Analysis

Peat accumulation in the catotelm can have three general trajectories as shown in Figure 3 (subsection 1.2). The rate of decay is directly proportional to the amount of mass left (Jenny et al. 1949; Clymo 1984):

$$\mathrm{d}m \;/\; \mathrm{d}t = -am, \tag{1}$$

where m is the mass at time t, α is the decay parameter.

The solution is:

$$m = m_0 \; e^{-\alpha t} . \tag{2}$$

where m_0 is the original mass.

This equation implies that there is always some of the plant material left, and a plot of logarithmically scaled m vs. t is a straight line (Clymo 1984).

Clymo's concave curve was originally based on Ingram's (1982) hydrological model. Water flows laterally in the acrotelm but there is almost no lateral flow in the water-saturated catotelm. The average water table or the boundary therefore rises at the same rate at which peat accumulates. Based on the exponential decay model (equation 1), a more specific model for the peat accumulation in the catotelm can be described with a constant peat addition rate, p (the rate of peat mass input from the bottom of the acrotelm), and decay at a rate (α) proportional to the amount of mass (x) at any time (t):

$$dx / dt = p - \alpha x . \tag{3}$$

The solution is:

$$x = \frac{p}{\alpha}(1 - e^{-\alpha t}) . \tag{4}$$

In this equation, the present surface of the catotelm can be arbitrarily set at any depth and the other values of mass and age are expressed relative to that depth, and p and α have been constant over the time under consideration. Equation 3 generates an age-depth (or cumulative mass) curve in a concave shape. The concavity indicates a long-term trend which cannot be explained by change in bulk density only; it is suggested there is decay ($\alpha > 0$) in the catotelm (Clymo 1984). Most of the mass loss in the catotelm is attributed to the fact that the decayed organic matter leaves the system through diffusion, by mass flow in solution, and by gas bubbles of methane (Gorham 1991).

For core TB07-1 from Tannersville Bog, I applied the calibrated radiocarbon ages obtained from the peat core and the ash-free bulk density to calculate cumulative peat mass and apparent peat accumulation rates. Based on the calculation, I used the Clymo concave model (equation 4) to estimate parameters including long-term peat-addition rates and catotelm decomposition rate in Tannersville Bog. Exponential regressions have been conducted on different continuous periods of time to explore the variations of peat addition rate (p) and decomposition rate (α) with time.

4 Results

4.1 Radiocarbon Dates and Chronology

One of twelve radiocarbon dates (Table 1) were rejected: the date at depth of 375-376 cm is reversed (Figure 9). The 11 accepted calibrated ages were used in the age-depth model using a cubic polynomial regression curve (Figure 9). The square of the correlation coefficient (R^2) is 0.9991. The p-values of all regression coefficients are less than 0.0001, which means all the regression coefficients are statistically significant. Based on this age model, the temporal sampling resolution ranges from 4 to 18 years for each contiguous 1-cm interval. A time scale based on this age model is used in this study.

Table 1 AMS radiocarbon dates obtained from core TB07-1 at Tannersville Bog.

Depth (cm)	Material dated	AMS No.*	14C yr BP	Calibrated year BP** (95% range)
99-100	Needles, Ericaceae leaves, woody fragments	38081	340±30	394.5 (326-473)
199-200	Ericaceae leaves, woody fragments	38082	1250±30	1217.5 (1170-1265)
235-236	Ericaceae leaves, woody fragments, seed	42064	1540±25	1439 (1370-1519)
299-300	Ericaceae leaves	38083	2010±30	1959 (1923-1995)
***375-376	Ericaceae leaves, needles, woody fragments, sedge s	42065	1535±25	1420 (1381-1509)
498-500	Ericaceae leaves, woody fragments, sedge leaves	38084	4305±40	4856.5 (4836-4877)
598-600	Ericaceae leaves, woody fragments, sedge leaves	38085	5555±50	6348.5 (6299-6398)
698-700	Ericaceae leaves, woody fragments, sedge leaves	38086	7320±80	8107 (8018-8196)
711-713	Peat	42066	7365±25	8183 (8046-8307)
799-800	Ericaceae leaves, woody fragments, sedge leaves	38087	7420±40	8251.5 (8185-8318)
898-900	Ericaceae leaves, woody fragments, sedge leaves	38088	8910±50	10047 (9916-10178)
1013-1014	Ericaceae leaves, woody fragments, sedge leaves	38089	9565±40	10912.5 (10745-11080)

*: AMS ^{14}C dates were measured in KCCAMS UCI;

**: calibrated ages are the median of 95% probability;

***: date at depth of 375-376 cm was rejected and not used in the age model.

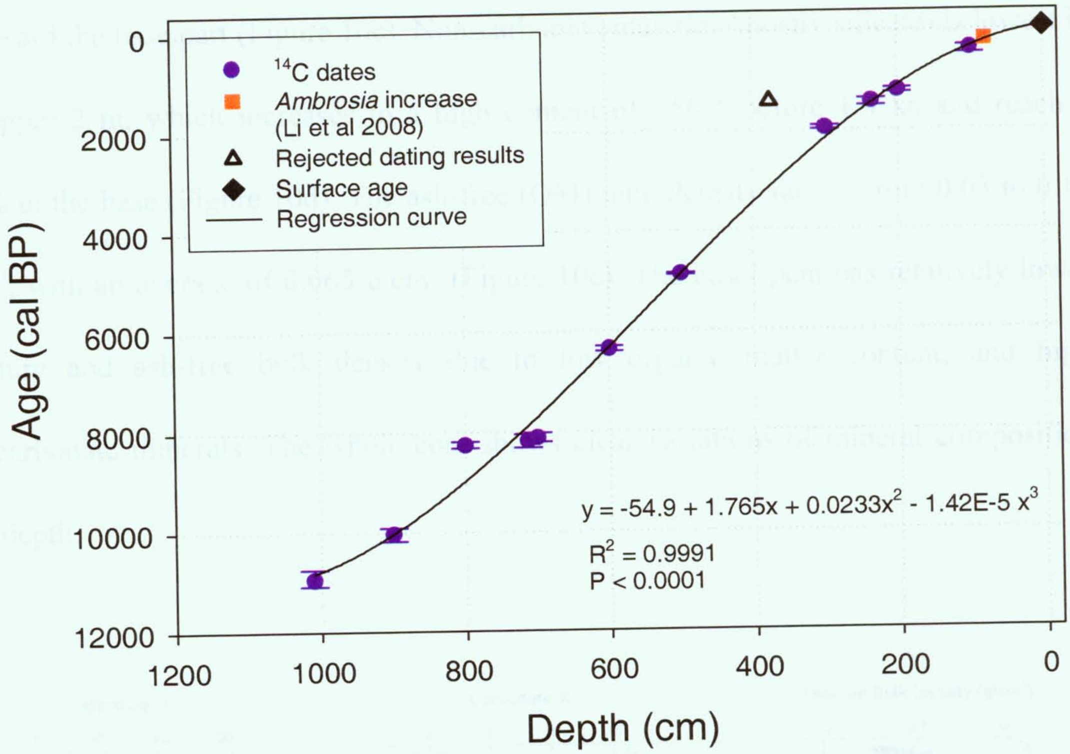

Figure 9 Age-depth model for core TB07-1 using cubic polynomial regression on calibrated AMS ^{14}C dates.

4.2 Sediment Lithology

The peat moisture content of the core TB07-1 ranges from 90% (top 8 m) to 75% (Figure 10a). The organic matter (OM) content of the dry material is highest (~96%) for the upper 2 m (0-1.4 ka), which decreases to ~50% below 2 m (from ~1.4 to 9 ka), and further declines to <30% at the base of the core (Figure 10b). The remaining dry material consists of carbonate and non-carbonate silicate minerals. The carbonate content of the dry material is lowest in the upper 2 m, and has an excursion up to 10% at the middle part (1.4-3.4 ka) of the peat core, while the value declines to ~5% for the lower part from ~3.2

ka toward the base part (Figure 10c). Non-carbonate material (mostly silicate) is lowest in the upper 2 m, which increases to a high content of ~50% before 1.4 ka and reaches ~80% in the base (Figure 10d). The ash-free (OM) bulk density ranges from 0.03 to 0.11 g/cm^3, with an average of 0.065 g/cm^3 (Figure 10e). The basal peat has relatively lower moisture and ash-free bulk density due to low organic matter content, and high non-carbonate minerals. The whole core shows clear variations of mineral composition with depth.

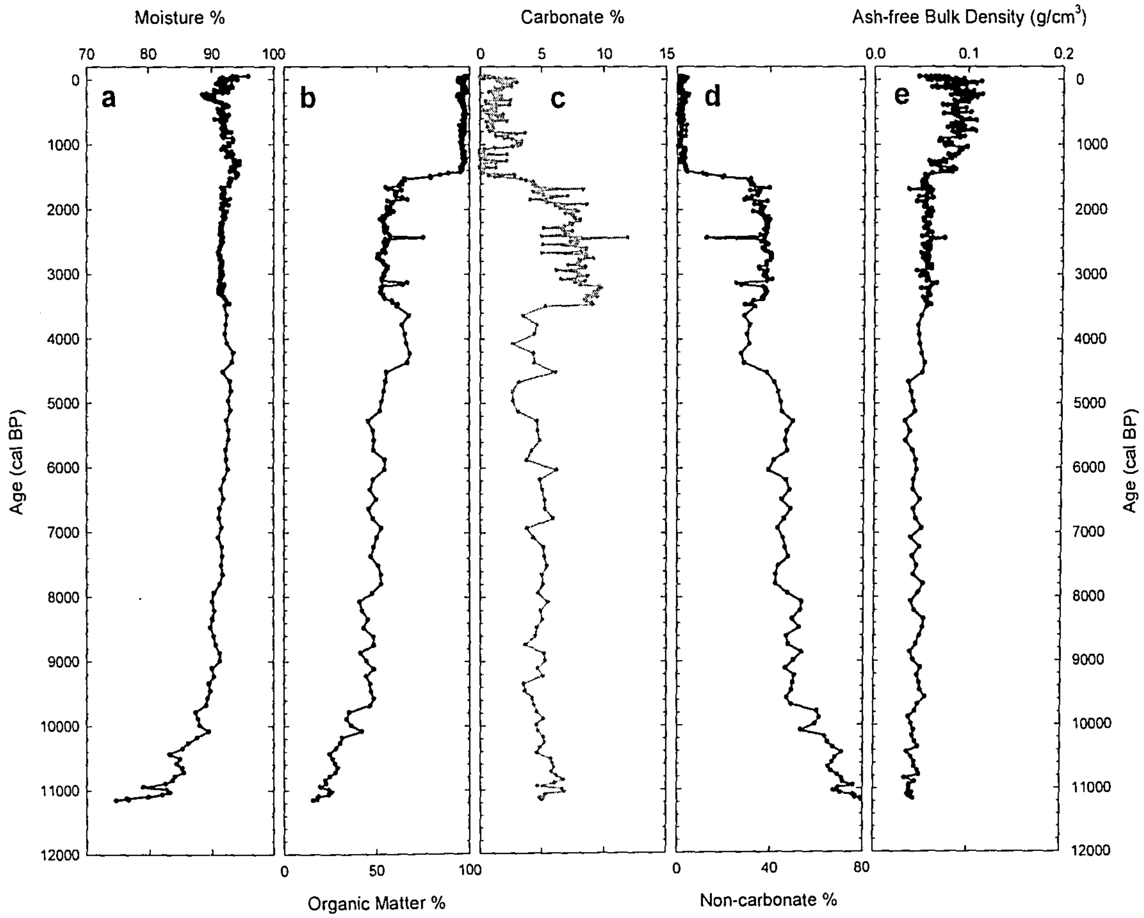

Figure 10 Sediment lithology of core TB07-1. a, moisture content; b, organic matter

content; c, carbonate content; d, non-carbonate (silicate) content; e, ash-free bulk density.

4.3 Humification

The peat humification measurements on samples for the last 3500 years from Tannersville Bog demonstrate that the transmission at 540 nm ranges from 51.7% to 68.8% (Figure 11). Compared to other North American peatlands (Sousa 2008), the results suggest that the peat appears to be less humified and presumably under relatively stable hydrological conditions. Four humification zones were defined by visual inspection (Figure 11). Zone H-1 (3.4-1.5 ka) has relatively high transmittance of ~62-68% with moderate variability, suggesting low decomposition and wet conditions. Zone H-2 (1.5-0.9 ka) has the lowest transmittance of 52% with values fluctuated between 50% and 60%. Except for one data point, H-2 represents relatively high peat decomposition and dry conditions. H-3 (0.9-0.4 ka) is characterized by intermediate humification with relatively small variability, which represents a period with relatively stable moist conditions. In contrast to the other zones, H-4 (0.45 ka-present) has the largest variations in transmittance with relatively low values on average, which suggest frequently changed moisture availability under generally dry conditions in the last 500 years.

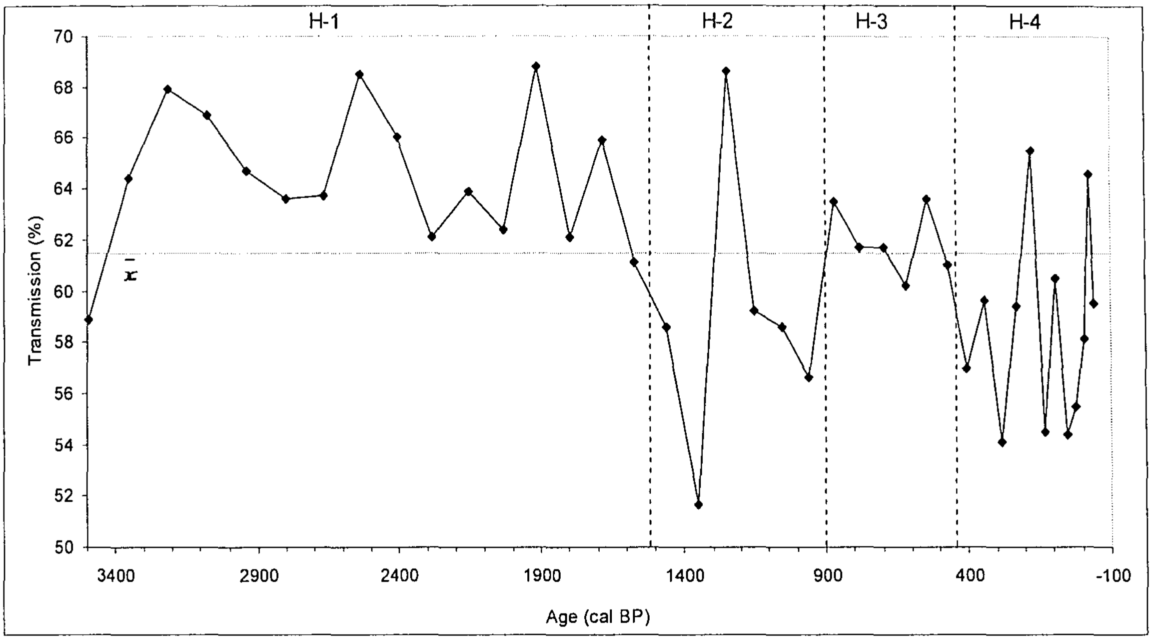

Figure 11 Humification for peat samples from the top 400 cm at 10-cm sampling interval measured as percent of transmission at 540 nm. The horizontal line ($\bar{x}$) is the numerical average of humification (61.5%) in the last 3500 years.

4.4 Macrofossil Record

Five plant macrofossil zones have been identified by visual inspection of dominant components (Figure 12). The macrofossil results show that the basal "peat" (11-9 ka) is dominated by filamentous green alga, woody material and charcoal with low brown moss leaves, suggesting an open water environment (zone M-1, Figure 12). Zone M-2 (9-5 ka) is dominated by brown moss leaves and stems with low abundance of woody materials and Cyperaceae leaves, which indicates a characteristic of rich fen vegetation. Zone M-3 (5-2.7 ka) is characterized by decline of brown moss, prevailing absence of Cyperaceae, and high abundance of fine debris, indicating a dry condition.

Zone M-4 (2.7-1.4 ka) shows a recovery of brown moss abundance with a decrease of detritus component toward the top of the zone. There is a major shift of dominant plant macrofossil from M-4 to M-5. Zone M-5 (1.4-0.2 ka) is characterized by the high abundance in Cyperaceae leaves and roots, increased abundance of *Larix* needles, Ericaceae leaves and roots, and woody fragments, presence of low abundant *Sphagnum* leaves, and the absence of brown moss. Zone M-6 (0.2 ka -present) is dominated by *Sphagnum* leaves and stems, *Picea* and *Larix* needles, Ericaceae leaves and roots, and decreased Cyperaceae leaves and roots. In this zone, brown moss leaves are only present in a few samples at ~250-200 years BP and may indicate a wet event during this time period. Microscopic charcoal pieces are present in all five zones, but tend to be more abundant before 3 ka. Filamentous green alga was present before 10 ka, indicating a lake or pond environment. Insect remains (e.g., chitin) were most abundant in zone M-2 and zone M-3.

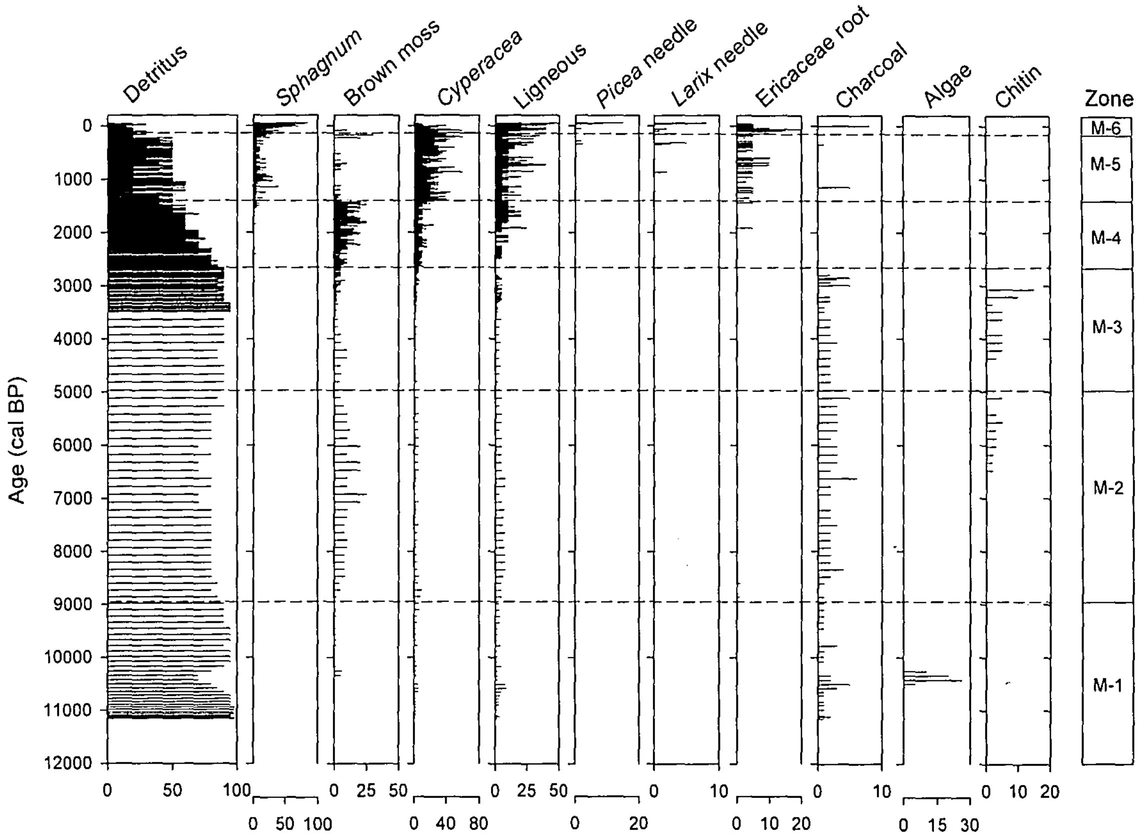

Figure 12 Plant macrofossil diagram of core TB07-1 from Tannersville Bog.

4.5 Pollen Record

Pollen diagram for core TB07-1 is divided to six pollen zones based on CONISS dendrogram using the pollen types with a maximum abundance >2% (Figure 13). The basal zone P-1 (11.1-11 ka) has 50% *Pinus*, 30% *Betula*, ~5% *Picea*, <10% *Quercus*, and low amounts of *Tsuga*, *Alnus*, *Fraxinus*, *Populus*, and other herbs and ferns. This zone represents the end of the spruce-dominated woodland before the Holocene (Deevey 1939; Watts 1979). Zone P-2 (11-9.8 ka) has 20-60% *Pinus*, 10-40% *Quercus*, 10% *Tsuga*, <5% *Picea* and *Betula*, and other herbs and ferns. This zone represents a mixed forest at the very early Holocene. Zone P-3 (9.8-4.9 ka) is dominated by *Quercus* (50-60%) and *Tsuga* (~20%), with <10% of *Pinus*, *Betula*, *Fagus* and others, representing a mixed oak forest during the early Holocene. Compared with zone P-3, zone P-4 (4.9-2.9 ka) is characterized by the low *Tsuga* pollen to 0-2% and more *Pinus* (10-20%) and *Picea* (~5%) pollen and the presence of *Osmunda* spores. This zone represents a dry climate. In zone P-5 (2.9-0.22 ka), *Tsuga* pollen recovered to 10%, associated with an increase in *Picea*, *Carya*, *Fagus*, Ericaceae, *Nuphar*, *Salix*, Poaceae pollen and *Sphagnum* spores. The very top zone P-6 (0.22 ka-present) is characterized by a sudden increase in *Ambrosia*, Ericaceae and Cyperaceae pollen. *Sphagnum* spores are present almost throughout the profile but increase in the last 3000 years (to 15%).

The pollen concentration calculated for each zone at Tannersville Bog ranges from 20,000 to 500,000 grains/cm^3 (Figure 14 and Table 2). The age-depth model and chronology in Figure 9 were used to calculate sedimentation rates and pollen accumulation rates ranging from 8,000 to 117,000 grains/cm^2/yr (Table 2).

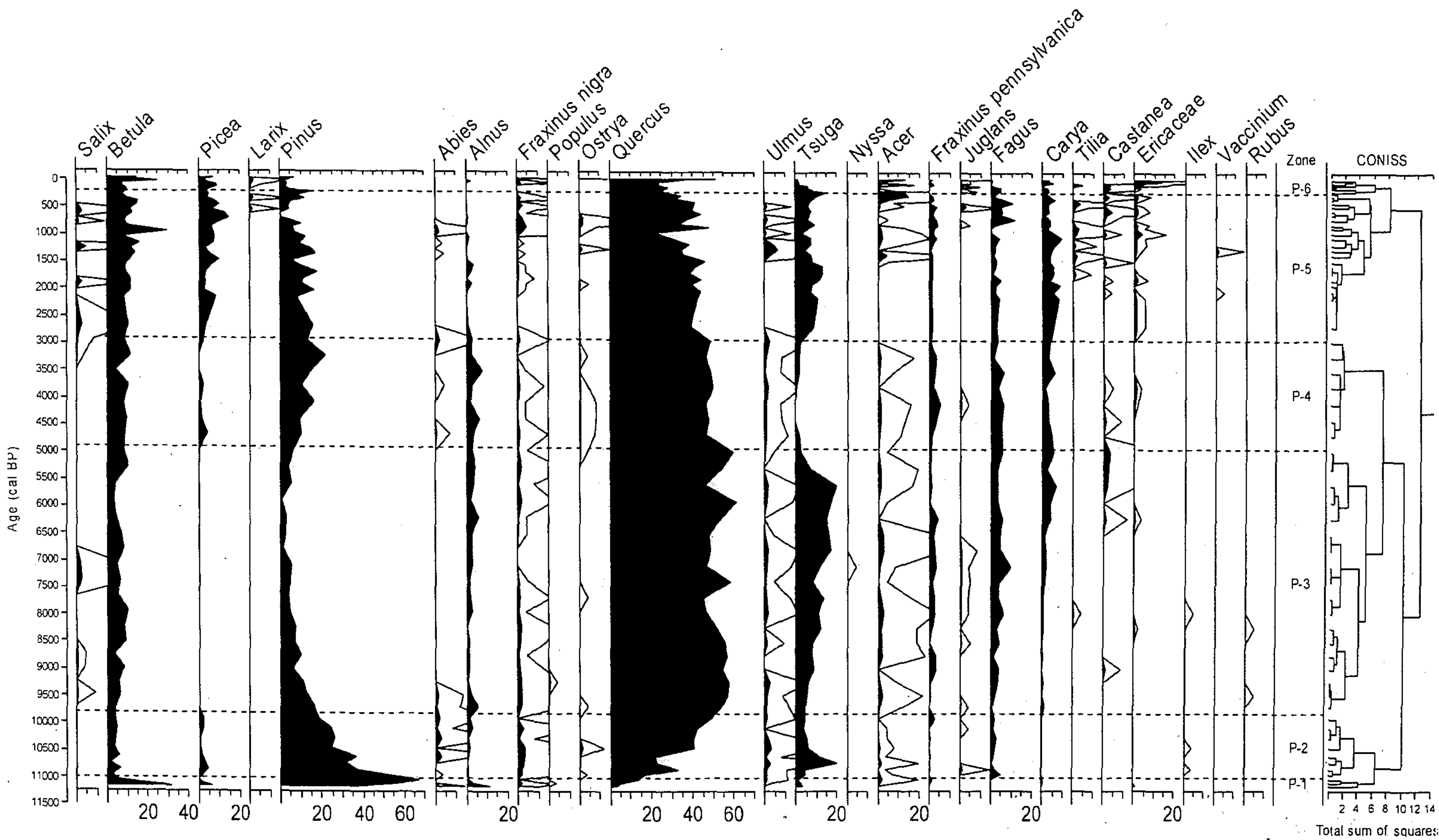

Figure 13 Pollen diagram of core TB07-1 at Tannersville Bog.

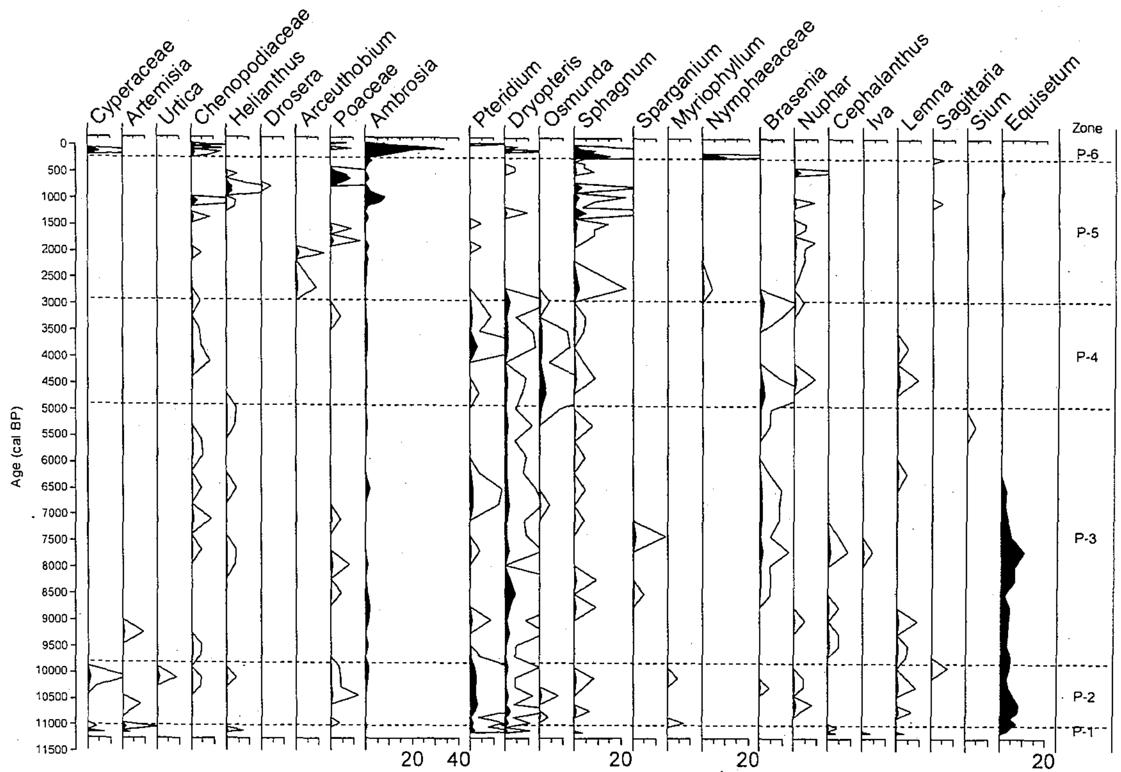

Figure 13 Continued.

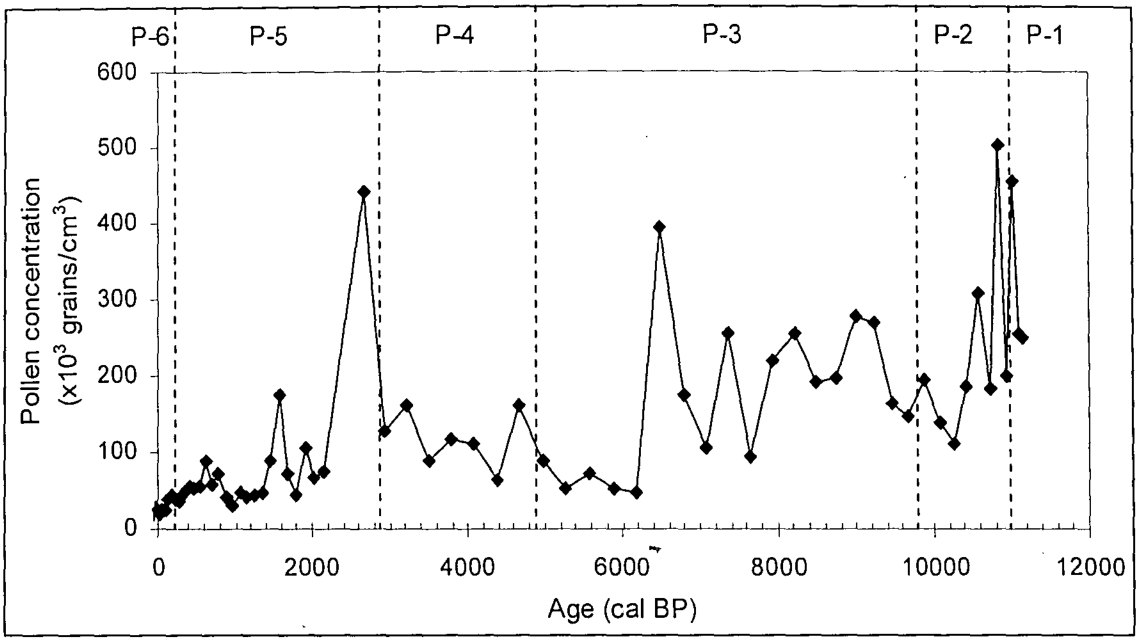

Figure 14 Total pollen concentrations at Tannersville Bog.

Table 2 Pollen concentration and accumulation rates from each pollen zone at Tannersville Bog.

Pollen zone (this study)	New England pollen Zone (Deevey 1939)	Pollen concentration ($\times10^3$ grains/cm^3)	Pollen accumulation rate ($\times10^3$grains/cm^2/yr)	Pollen accumulation rate at equivalent zones in Watts (1979) ($\times10^3$grains/cm^2/yr)
P-6 (last 200 years)	Present	40	9	n/d
P-5 (mixed oak)	C3 (oak forest)	50-450	8	n/d
P-4 (hemlock decline)	C2 (hemlock minimum)	150	8	12
P-3 (pine minimum)	C1 (oak forest)	50-400	13	10-16
P-2 (pine peak)	B (mixed forest)	100-500	34	22
P-1 (mixed forest)	A (spruce woodland)	300	117	17

4.6 Testate Amoebae and Water Table Depth Reconstruction

Twenty-six testate amoebae taxa have been identified in the upper 3.4-m section (the last 2700 years) of Tannersville Bog core TB07-1 (Figure 15). The maximum abundance of each identified taxa is larger than 5%, though their abundance varied widely. Four zones were defined by stratigraphically constrained cluster analysis using CONISS, and descriptions of these zones are presented in Table 3.

Table 3 Testate amoeba zone descriptions for core TB07-1 at Tannersville Bog.

Zone	Depth (cm)	Age range (cal BP)	Dominant taxa	Zone description
A-4	0-58	80 to -57	*Hyalosphenia subflava* *Nebela militaris/minor*	*Cyclopyxis-Phryganella*, *Arcella discoides*, *Difflugia pulex*, *Euglypha* spp. and *Trigonopyxis arcula* are variably abundant in this zone.
A-3	58-85	200-80	*Centropyxis aculeate*, *Hyalosphenia papilio*	*Amphitrema flavum* and *Hyalosphenia papilio* and *H. elegans* all increase, *Arcella discoides* decreases in abundance toward the top of the zone.
A-2	85-235	1400-200	*Amphitrema flavum*, *Centropyxis aculeate*, *Hyalosphenia sphagni*	*Arcella discodies*, *Hyalosphenia papilio*, *H. subflava*, and *Nebela militaris/minor* are variably abundant in this zone. Taxa diversity increased while several species were present for short time period.
A-1	235-340	2670-1400	*Centropyxis aculeate*	The abundance of *Nebela griseola* is variable. Sixteen species present.

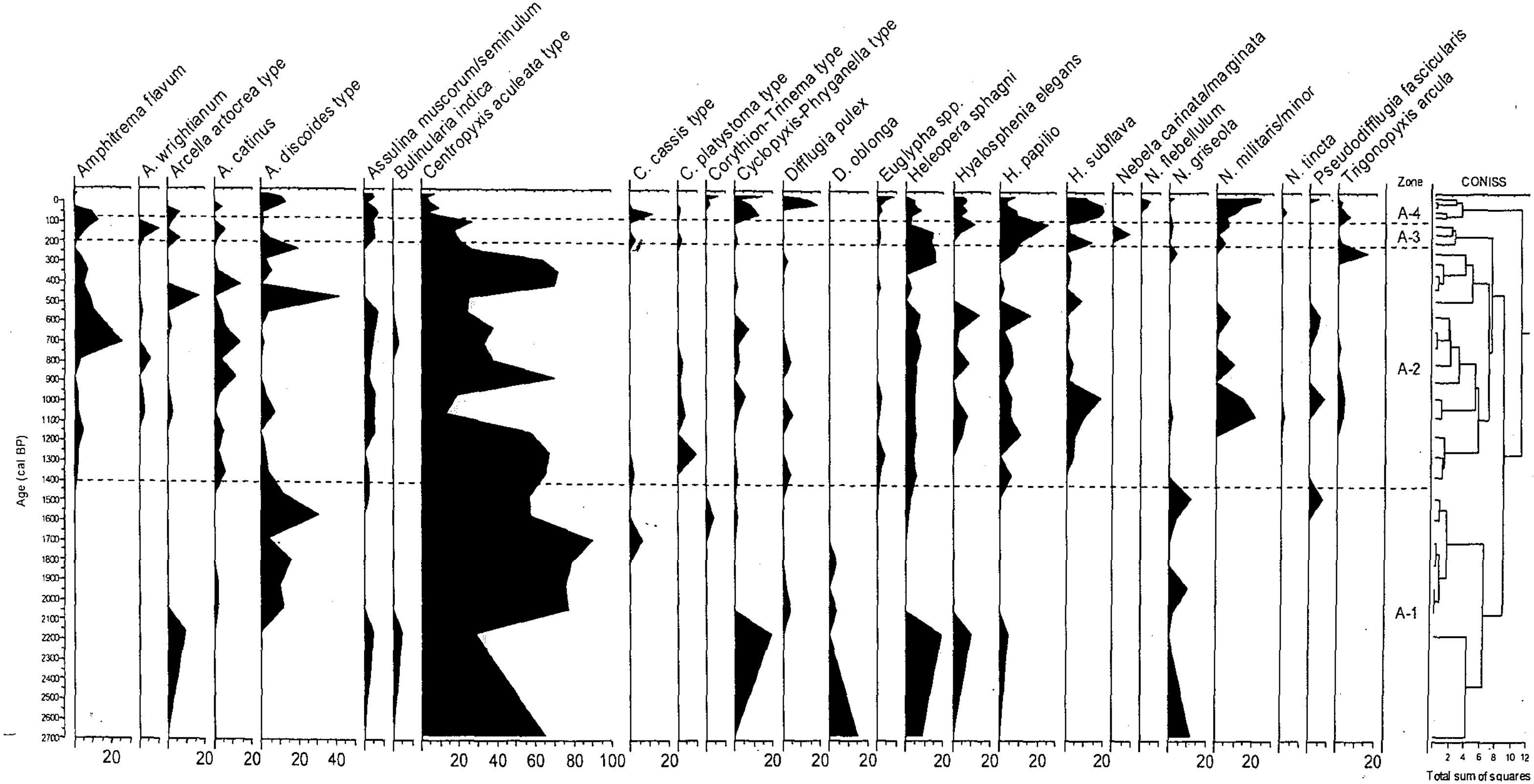

Figure 15 Testate amoebae diagram of core TB07-1 from Tannersville Bog.

The reconstructed water-table depth is shown in Figure 16. Zone A-1 (2670-1400 years BP) has a low water-table depth (5 cm), suggesting wet conditions. Zone A-2 (1400-200 years BP) has a low and fluctuated water-table depth (5-25 cm) compared to zone A-1. Zone A-3 (200-80 years BP) has an intermediate to low water-table depth of 16-7 cm. Zone A-4 (80 years BP – present) has the largest water-table depth of ~27 cm, suggesting the driest condition during the last 2700 years.

The water-table depths and the degree of peat humification show similar patterns although humification is more sensitive to the variation of substrate moisture conditions than testate amoebae is (Figure 16). Pollen, humification, and testate amoebae zones are also summarized in Figure 16. Pollen zone P-5 generally corresponds to testate amoeba zone A-1 and A-2 and hydrologic zone H-1 to H-3. Testate amoebae and humification both indicate that H-1 and A-1 (2300-1450 years BP) was the wettest time period in the last 2700 years, while pollen zone P-5 represents a recover of *Tsuga* abundance during this time period. Testate amoebae zone A-2 approximately includes hydrologic zones H-2, H-3 and part of zone H-4, except that H-2 (1460-960 years BP) started a few decades ahead of A-2. The major shift from wet to dry conditions from 1400 to 900 BP was recorded by both humification and testate amoebae. Zone H-4 (400 BP-present), corresponding to P-6 and A-3 & A-4, is characterized by fluctuating moisture conditions which is also indicated by testate amoebae-inferred water-table depth.

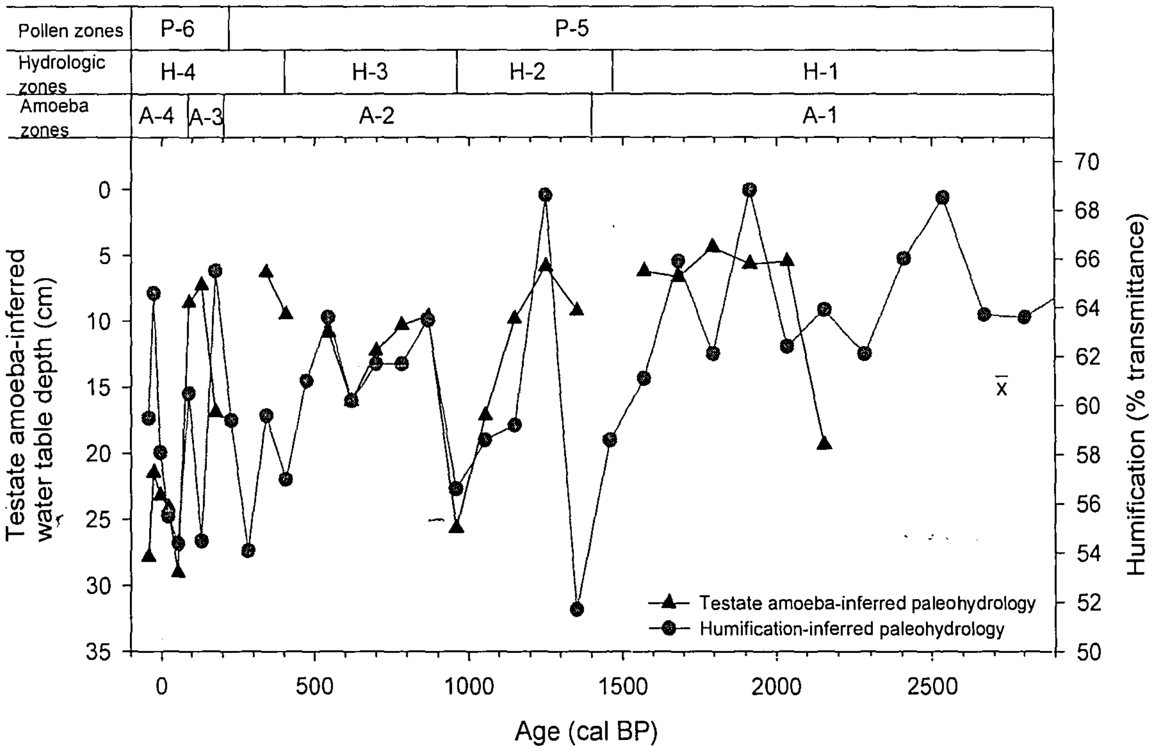

Figure 16 Testate amoeba-inferred water-table depth ($r^2 = 0.76$, RMSEP = 7.7) and peat humification-inferred paleohydrology of the upper 3.4-m section of core TB07-1. Gaps in testate amoeba-inferred water-table depth represent the intervals that reliable reconstructions can not be obtained due to low abundance of testate amoebae (amoebae sum < 50).

4.7 Diatom Abundance

The diatom concentration from the upper 340 cm peat core (the last 2700 years) shows large variations (Figure 17). Diatom has the highest concentrations up to 8 $\times 10^6$ valves/cm^3 in the lower part of this section (2700-1400 years BP). From 1400 to 340 years BP, the concentrations are lower than 2000 valves/cm^3 or absent. From 340 to 230 years BP, diatom increased to high concentrations of 4000-8000 valves/cm^3. In the upper part of the sediment spanning the last 230 years, diatom valves are absent. The high abundance of diatom corresponded with the high abundance of brown moss macrofossils and the high carbonate content at 2700-1400 years BP and at 340-230 years BP, suggesting wet or open water environments.

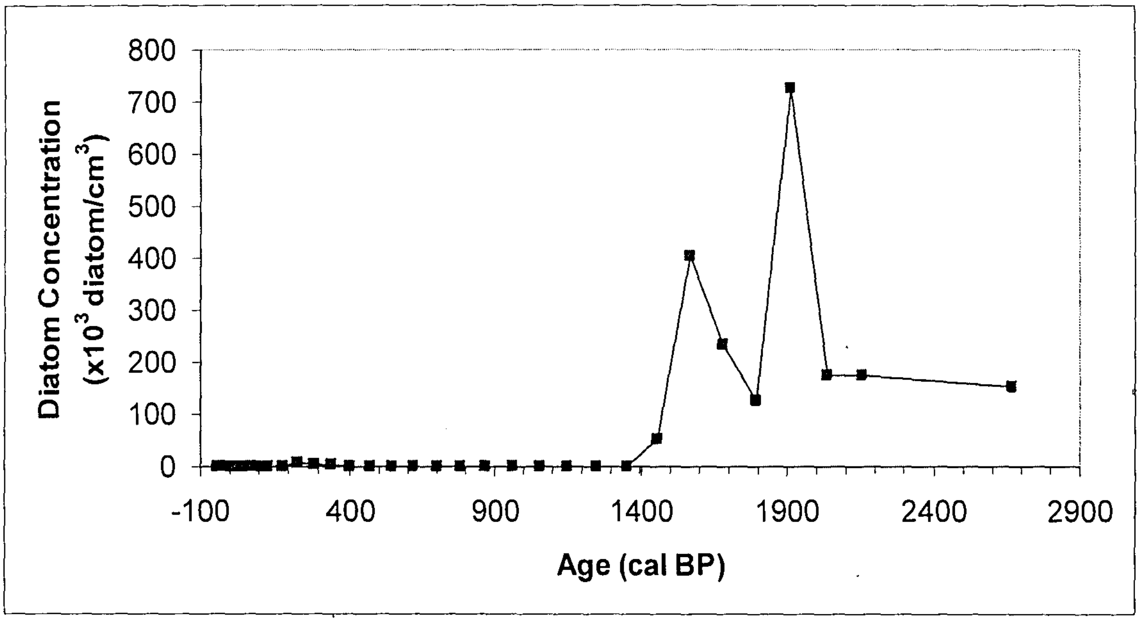

Figure 17 Diatom concentration counted from pollen/testate amoebae slides for the upper 3.4-m section of core TB07-1 (the last 2700 years).

4.8 Conceptual Modeling Results

The cumulative peat mass-age profile over the last ~11 ka based on 11 calibrated ^{14}C dates and 268 ash-free bulk density measurements shows a concave curve, similar to the patterns of oceanic bogs rather than continental fens (Figure 18). Fitted curves from different intervals and estimated parameters are shown in Table 4. Both peat-addition rates (p) and catotelm decomposition rates (α) increased with shorter length of records analyzed, from 129 g $m^{-2}yr^{-1}$ and 0.00023 yr^{-1} (for the last 10 ka) to 233 g $m^{-2}yr^{-1}$ and 0.00079 yr^{-1} (for the last 2 ka).

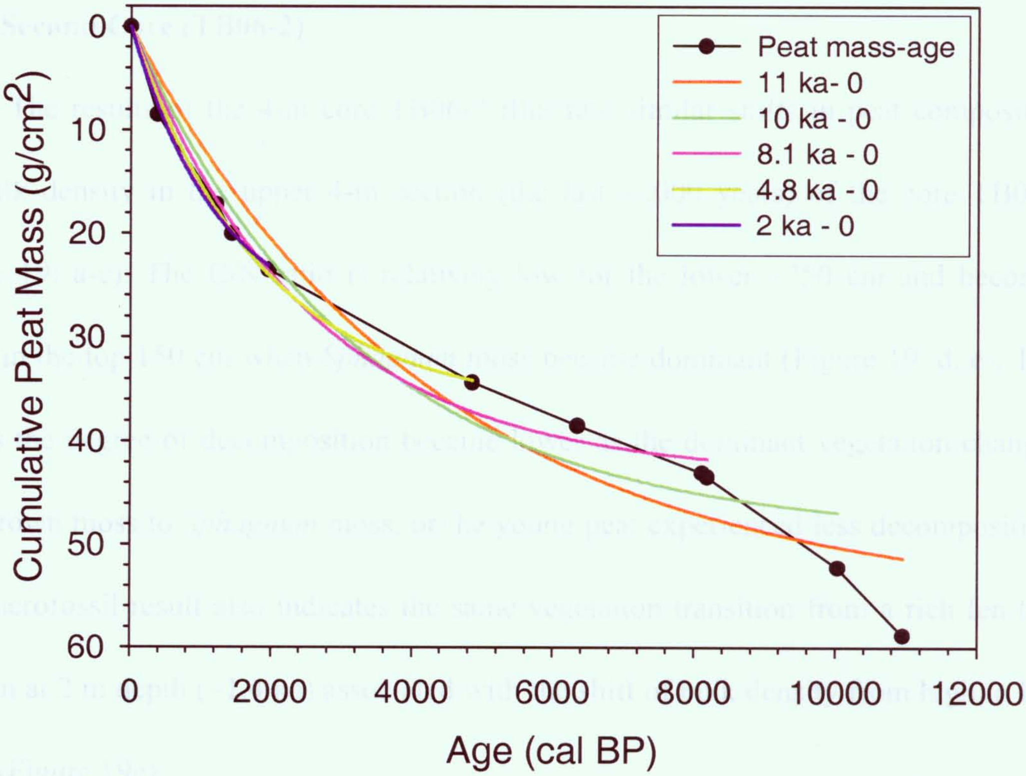

Figure 18 Cumulative peat mass-age profile and fitting curves for Tannersville Bog. The values of corresponded parameters are listed in Table 4.

Table 4 Estimates of long-term peat accumulation parameters (peat-addition rate and decomposition rate) by using a curve fitting analysis.

Age range (ka BP)	***p* (g $m^{-2}yr^{-1}$)**	***α* (yr^{-1})**
11-0	129.2	2.3×10^{-4}
10-0	152.2	3.1×10^{-4}
8.1-0	174.4	4.0×10^{-4}
4.8-0	198.9	5.4×10^{-4}
2-0	232.6	7.9×10^{-4}

4.9 Second Core (TB06-2)

The results of the 4-m core TB06-2 illustrate similar shifts in peat composition and bulk density in the upper 4-m section (the last ~4000 years) of the core TB07-1 (Figure 19: a-c). The C/N ratio is relatively low for the lower ~250 cm and becomes higher in the top 150 cm when *Sphagnum* moss became dominant (Figure 19: d, e). This implies the degree of decomposition became lower as the dominant vegetation changed from brown moss to *Sphagnum* moss, or the young peat experienced less decomposition. The macrofossil result also indicates the same vegetation transition from a rich fen to a poor fen at 2 m depth (~1.4 ka) associated with the shift of bulk density from high to low values (Figure 19e).

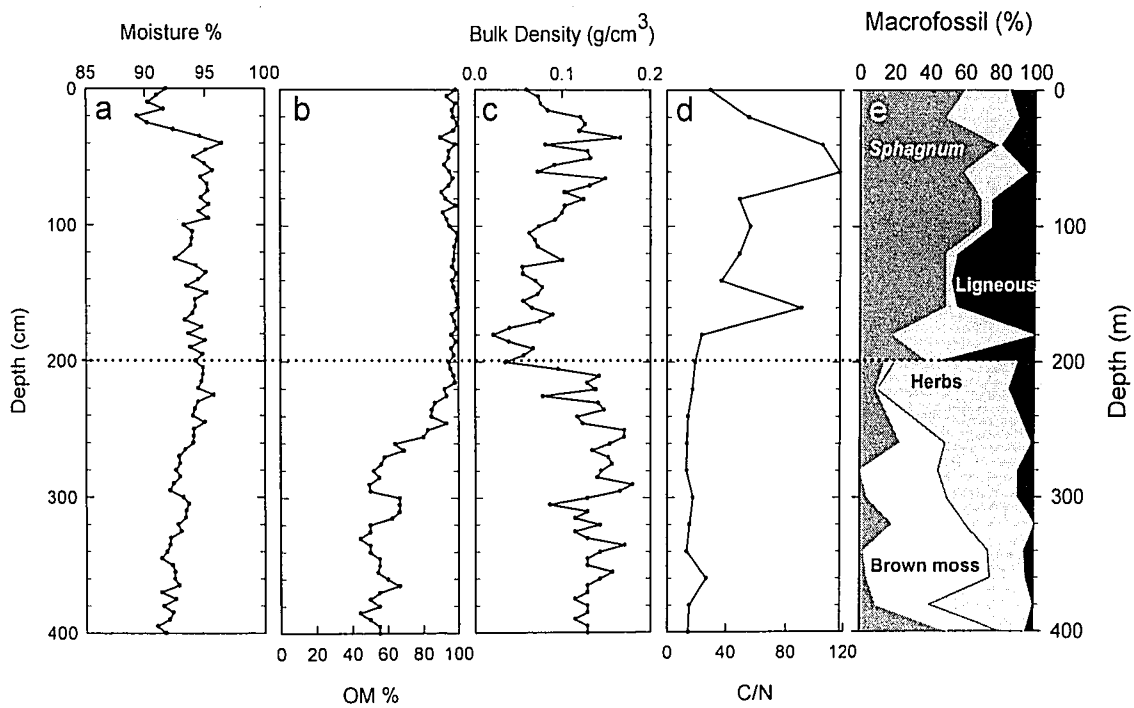

Figure 19 Lithology (moisture content, organic matter content, ash-free bulk density), C/N ratio, and plant macrofossil of core TB06-2 from Tannersville Bog (analyzed by the EES250 Terrestrial Ecosystem class in fall 2006).

5 Discussion

5.1 Peatland Development at Tannersville Bog

Tannersville Bog was initiated by the terrestrialization (lake infilling) of a glacial lake, as suggested by the abundance of non-carbonate minerals (i.e., silicate) (Figure 20) and the presence of aquatic fossils (e.g., green algae) and pollen (e.g., *Nuphar*) (Figure 12 and Figure 13). Gehris (1964) and Hirsch (1977) described the silty clay layer deposited beneath the peat in detail (see section 2). Both of the authors indicated that the peat is underlain by gray silty clay over bedrock at Tannersville Bog. Watts (1979) suggested that the lake-filling process started shortly after 8 ka and the "bog" (poor fen) environment had been established at about 4 ka. Peat initiation at Tannersville Bog might have responded to a warm climate in the early Holocene (Fisher et al. 1995). A gradual increase in organic matter content and presence of brown mosses from 11 to 9 ka (Figure 20) suggests increasing primary productivity of aquatic plants. Brown moss started to increase in abundance at 9 ka, prbably extending laterally around the coring site.

During the period of 9 to 5 ka, the brown moss leaves and stems dominated the macrofossil records at Tannersville Bog, while oak and hemlock pollen reached their highest values (Figure 20). Organic matter content increased slowly with a gradual decrease in carbonate and silicate contents in the sediments, which suggests the establishment of a stable rich fen environment during this time period. Brown moss macrofossils decline and fine debris (detritus) increase (to >90%) from 5 to 2.7 ka

(Figure 20), suggesting high decomposition during a dry climate interval. This time period corresponded with the decline of hemlock pollen from 5.5 to 3 ka, the slight increase in organic matter content and decrease in silicate content at Tannersville Bog. The decline of hemlock pollen has been documented in many studies (e.g., Foster et al. 2006), which corresponded with a dry time period inferred from low lake levels in northeastern North America (e.g., Yu et al. 1997). For example, it has been argued that this dry event was affected a dry climate at mid-Holocene which was driven by the change in atmospheric circulation patterns in North America. After 2.7 ka, brown moss recovered to become the dominant plant, along with a slightly increased abundance of sedges.

The transition from a rich fen to a poor fen at ~1.4 ka was characterized by decreased brown mosses, increased sedges and *Sphagnum*, as well as decreased input of ground water, suggested by decreased carbonate content (Figure 20). The increased organic matter content and decreased bulk density during the transition were the result of decreased carbonate content and silicate content, as well as the slow decomposition of *Sphagnum* liters (van Breemen 1995; Verhoeven and Liefveld 1997). A decrease in hemlock at the same time implied a dry condition (Figure 20). Watts (1979) illustrated a very similar shift of organic matter content and an increase in oak pollen percentage at a comparable time around 1.4 ka at Tannersville Bog.

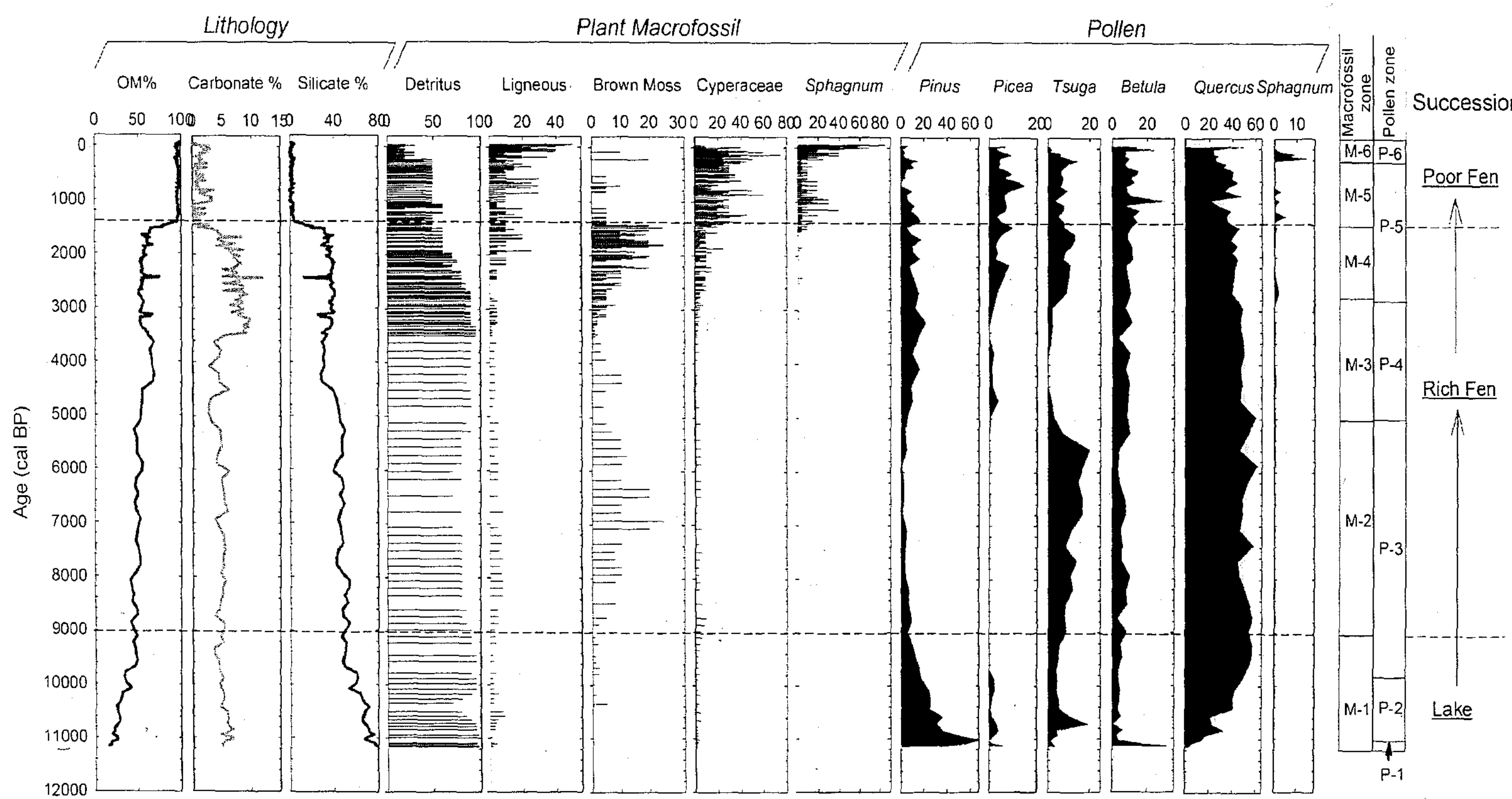

Figure 20 Correlation of lithology, plant macrofossil and pollen results core TB07-1 from Tannersville Bog.

5.2 Rates and Pattern of Carbon Accumulation

Long-term apparent rates of carbon accumulation range from 13.4 to 101.2 g C m^{-1} yr^{-1} (Figure 21), which were calculated from 268 ash-free bulk density measurements (Figure 10e) and peat vertical growth rates (Figure 9) using the average carbon content of peat organic matter (51.8%) derived from peatlands in continental western Canada (Vitt et al. 2000). The apparent rates at Tannersville Bog started an increasing trend from ~8 ka and reached the highest value in the last 400 years. The long-term (time weighted) average rate of carbon accumulation for core TB07-1 from Tannersville Bog is 27.2 g C m^{-1} yr^{-1} for the last 11.1 ka or 27.3 g C m^{-1} yr^{-1} for the last 8.2 ka. This value is higher than the rates of subarctic and boreal peatlands (Figure 21, Table 5), such as peatlands in western Canada (Vitt et al. 2000), eastern Canada (Roulet et al. 2007), Alaska (Cai and Yu unpublished data), northwestern Canada (Vardy et al. 2000), and Finland (Makila 1997; Makila et al. 2001).

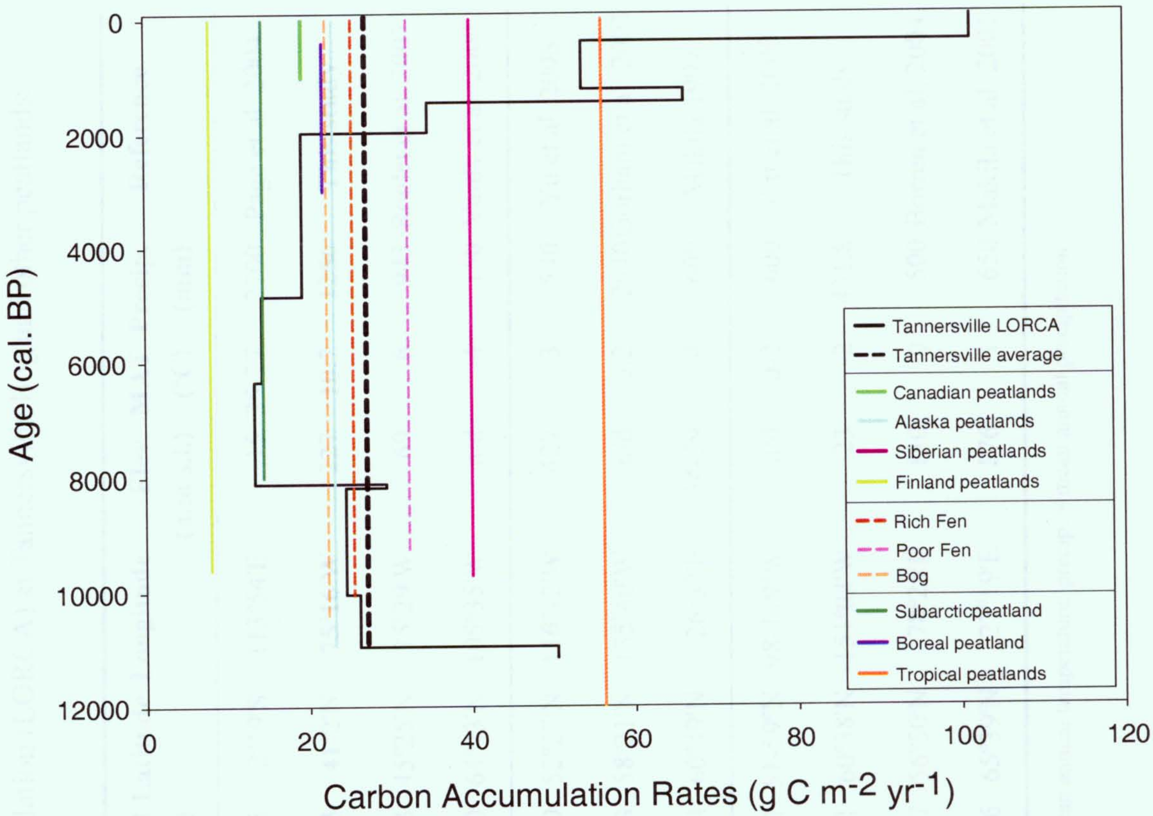

Figure 21 Comparison of apparent carbon accumulation rates at Tannersville Bog and long term apparent rates of carbon accumulation (LORCA) from other peatlands. See Table 5 for details and references.

Table 5 Comparison of long-term rates of carbon accumulation (LORCA) at Tannersville Bog and other peatlands.

Type	Site	Peatland Type	LORCA ($gC/m^2/yr$)	Period (ka)	Latitude	Longitude	Elev. (a.m.s.l.)	MAT (°C)	Precip. (mm)	Reference
Tropical	Kalimanthan, Indonesia	n/d	56.2	8.6-9.5	2°19'S	113°54'E	15	25-27	2700	Page et al. 2004
Temperate	**Tannersville Bog, PA**	**Poor Fen**	**27.2**	**0.4-8.3**	**41°2'N**	**75°16'W**	**227**	**10.7**	**1256**	**This study**
Boreal	Mer Bleue, ON	Bog	21.9	0.4-3	45°25'N	75°29'W	69	6	943	Roulet et al. 2007
Subarctic	Western Nunavut	Fen	14.5	8-0	64°43'N	105°35'W	n/d	-4	150	Vardy et al. 2000
Rich fen	Goldeye Lake, AB	Rich fen	25.5	0-10	52°27'N	116°12'W	427	3	540	Yu et al. 2006
Poor fen	Peatland Island, AK	Poor fen	32.3	0-9.3	58°21'N	135°40'W	n/d	5.2	2940	Gorham et al. 2003
Bog	Haukkasuo, Finland	Bog	22.3	0-10.4	60°49'N	26°57'E	54-59	4	600	Makila 1997
Canadian	Western CA	Fens	19.4	0-1	51-59°N	98-119°W	n/d	0-2	600	Vitt et al. 2000
Alaska	No Name Creek, AK	Poor fen	23.2	0-11	60°38'N	151°04'W	23	-2	431.8	This study
Siberian	Plotnikovo	Bog	40	0-9.7	56°50'N	78°25'E	130	0	500	Borren et al. 2004
Finland	Ruosuo mire	Mire	8	0-9.6	65°39'N	27°19'E	176	1	650	Makila et al. 2001

Notes: n/d = no data; Elev. = elevation; a.m.s.l. = meter above sea level; MAT = mean annual temperature; precip. = mean annual precipitation.

The high rate of carbon accumulation at Tannersville Bog could result from high primary production or low peat decomposition or both. The significant higher peat addition rate (p) and similar peat decomposition rate (α) at Tannersville Bog, compared to those in boreal peatlands (Table 6) (Clymo 1984; Yu et al. 2003), indicate that the higher primary production have more likely contributed to the high rate of carbon accumulation at Tannersville Bog, because of warmer and wetter climate characterizing temperate regions than that in boreal regions. Table 6 also shows that the net primary production of peatlands in temperate regions is around four times of the production of peatlands in boreal regions (Carroll and Crill 1997; Wieder et al. 2006).

Table 6 Comparison of peat addition rate and decomposition rate at Tannersville Bog with boreal peatlands, and net annual primary production in temperate and boreal regions.

Peatland	**Region**	**Peat addition rate (p, g m^{-2} yr^{-1})**	**Decomposition rate (α, yr^{-1})**	**Reference**
Tannersville Bog, PA	Temperate	174	4×10^{-4}	This study
Upper Pinto Fen, AB	Boreal	26	3.7×10^{-4}	Yu et al. 2003
Finland	Boreal	~50	10^{-4}	Clymo 1984
Siberian	Boreal	42	10^{-5}	Borren et al. 2004

Region	**Net annual primary production of peatlands** g m^{-2} yr^{-1}	g C m^{-2} yr^{-1}	**Reference**
Temperate	~1800	~900	Wieder et al. 2006
Boreal	~500	~250	Carroll and Crill 1997

Temperature and moisture are the most important factors influencing the rates of carbon accumulation and decomposition. Temperature can affect carbon sequestration through controlling the processes of photosynthesis and respiration (Carroll and Crill 1997). The mean annual temperature at Tannersville Bog is much higher than all the boreal regions (Table 5), which may provide a favorable environment for plant growth under a longer growing season and shorter freezing season compared to boreal regions. Although higher decomposition rates have been expected under higher temperature in temperate region (Davidson and Janssens 2006), inferred decomposition rate at Tannersville Bog is similar to those of boreal peatlands (Table 6) which may be the result of a high and stable water table maintained by significantly higher and evenly distributed precipitation among seasons in northeastern Pennsylvania, and by the beneficial hydrology at Tannersville Bog such as the nearby stream and the partially floating property .

Precipitation controls the moisture available to vegetation and the water-table depth of peatlands which affects the anoxic decomposition and therefore carbon accumulation. Northeastern Pennsylvania has a mean annual precipitation of 1200-1600 mm (NOAA data), which is almost double of the precipitation at most of the boreal peatlands (Table 5). Gorham et al. (2003) reported a higher LORCA value of a poor fen from Peatland Island, Alaska (32.3 g C m^{-1} yr^{-1}) associated with a high annual precipitation of 2940 mm. A tropical peatland studied by Page et al. (2004) also has a great value of annual precipitation (2700 mm) and a high LORCA of 56.2 g C $m^{-1} yr^{-1}$, which appears to support the significant influence of precipitation on primary production and further the rate of carbon accumulation. Borren et al. (2004) reported a high LORCA of 40 g C $m^{-1}yr^{-1}$ from a Siberian peatland (Table 5), with a peat addition rate similar to those for boreal peatlands (Table 6); but the peat-addition rate is 10 times lower than Tannersville Bog, probably due to low annual precipitation.

Besides the environmental controls of temperature and precipitation regimes on primary production and decomposition, some other environmental factors should also be considered during the processes of peat accumulation, including hydrology, microbial communities, nutrients, and light. Tannersville Bog has a watery pocket at the depth of 1.5-2 m which varies in thickness during the year (Maura Sullivan, 2008 personal communication). The floating character tends to have a high rate of peat accumulation due to the special hydrology (Campbell et al. 1997; Asada et al. 2005), which further influence the microbial communities and decomposition of the upper part of the peatland (Dickinson 1983). Nutrient availability is generally higher at minerotrophic fens than bogs, while competition for light tends to be high at sites with high productivity and low in peatlands lack of nutrients (Rydin and Jeglum 2006). The floating property of Tannersville Bog is suggested to contribute to the low decomposition indicated by the low humification (high transmittance) during the last 2000 years, comparing with other similar floating peatlands and non-floating peatlands in North America (Sousa 2008).

Therefore, the low decomposition during the late Holocene might also have contributed to the high carbon accumulation rates at this study site.

5.3 Autogenic and Allogenic Controls of Peatland Succession

It has been suggested that autogenic processes play a major role in the development of peatlands (hydroseral succession: aquatic → rich fen → poor fen → bog), such that the establishment of *Sphagnum* follows the transition to a bog eventually (Tansley 1939; Rydin and Jeglum 2006). However, many paleoecological studies on peatlands show that allogenic factors, such as climate change and human impact, can affect the pattern of change and the timing of the transitions along the classic pathway of peatland development (Walker 1970; Foster 1984; Campbell et al. 1997; Huber and Markgraf 2003; Booth et al. 2004). The transition at Tannersville Bog from a rich fen to a poor fen at ~1.4 ka (Figure 22) was associated with the transition of testate amoebae and humification zones from A-1 to A-2 and H-1 to H-2, respectively. The association between plant macrofossil-inferred local vegetation change and testate amoebae and humification-inferred hydrologic change indicates that the transition of vegetation succession might have been triggered by allogenic factor such as hydrologic change at the study area. The decreased carbonate content might have resulted from a decreasing groundwater input to the peatland, which is also supported by the suppressed diatom frequency and the shift from wet to dry in humification-inferred moisture conditions (Figure 22).

A dry event at ~1.3 ka was inferred from a low lake level time period based on paleomagnetic records at White Lake in New Jersey (Li et al. 2007). This dry event might have corresponded with the hydrologic change (~1.4 ka) at Tannersville Bog. Slight age offsets between these two records are probably within the uncertainties of radiocarbon dating at both sites. Li et al. (2007) suggested that the dry event with the other three low lake level records at about 3.0, 4.4 and 6.1 ka are likely a response to the cold periods in the North Atlantic Ocean occurred every 1500 years during the Holocene (Bond et al. 2001). Bond et al. (2001) observed this millennial-scale cycle from changes in proxies of drift ice measured in deep-sea sediments. They argued that a solar forcing mechanism may underlie at least the Holocene segment of the North Atlantic's 1500-year cycle (Bond et al. 2001).

The spike of brown moss abundance at ~200 year BP (1750 AD) was associated with presence of diatoms and humification-inferred wet conditions (Figure 22). This spike simultaneously corresponded to the rise of *Ambrosia* (ragweed) pollen abundance during this time period (P-6) that marks the start of the European settlement of North America (Russell 1980; Willard et al. 2003). This short time period of wetness probably reflected the peatland response to the change in hydrology and surface water regimes that were induced by human activities such as deforestation (e.g., Campbell et al. 1997; e.g., Bunting et al. 1998; Lamentowicz et al. 2007). The study by Bunting et al. (1998) on Oil Well Bog in southern Ontario showed that when the upland forest was cleared by

European settlers (ca. AD 1830-1845), trees that colonized parts of the wetland was replaced by low shrub communities that dominated the area during wet periods before 500 BP, which suggested initially the wetland surface became wetter.

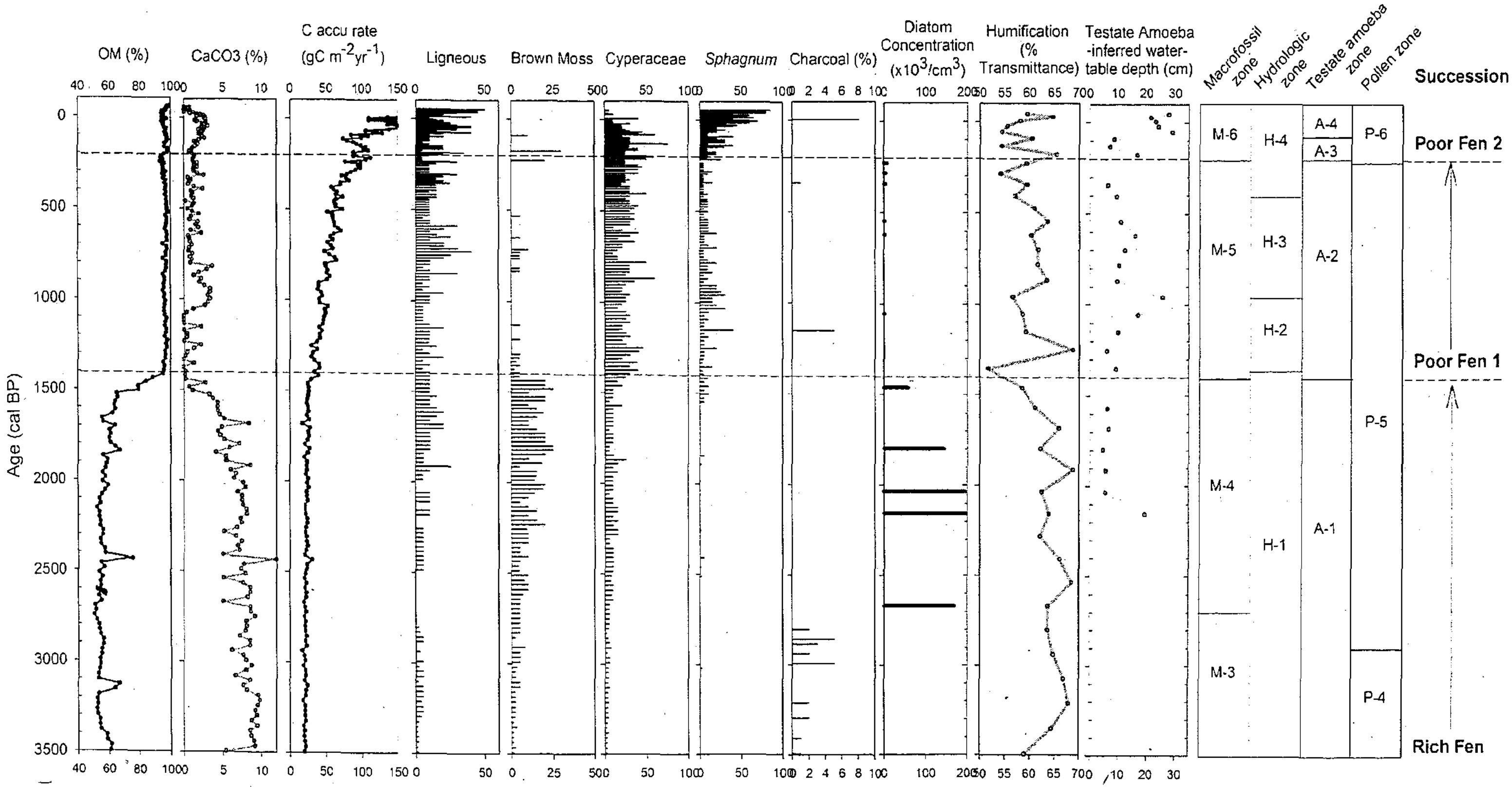

Figure 22 Summary graph of lithology (organic matter and carbonate content), apparent rate of carbon accumulation, plant macrofossil results, diatom concentration, humification, testate amoeba-inferred water-table depth, and zonation of macrofossil (M), humification (H), testate amoebae (A), and pollen (P), over the last 3500 years.

6 Conclusions and Implication

Peat accumulation at Tannersville Bog was initiated by the terrestrialization (lake infilling) of a glacial lake at ~9 ka with establishment of brown mosses in a rich fen. It shifted to a poor fen with abundant Cyperaceae and *Sphagnum* at ~1.4 ka and a *Sphagnum*-dominated poor fen at ~200 yeas BP.

As a boreal-type poor fen associated with a temperate climate, Tannersville Bog possesses a concave peat accumulation pattern, which is similar to the patterns of most oceanic bogs and different with those of most continental fens in boreal region, due to the warmer and wetter climate in temperate region. Apparent rates of carbon accumulation at Tannersville Bog range from 13.4 to 101.2 g C $m^{-1}yr^{-1}$, in the last 10 ka, with a long term average rate of carbon accumulation of 27.2 g C $m^{-1}yr^{-1}$. This value is higher than the rates of most northern peatlands in boreal and subarctic regions. The significant higher peat-addition rate (174 g $m^{-2}yr^{-1}$) and similar modeled peat decomposition rate (0.0004 yr^{-1}) at Tannersville Bog, compared to those in boreal peatlands, suggest that the high rate of carbon accumulation may have been caused by higher primary production. However, humification data is not consistent with this interpretation, and suggests that local hydrology (partially the floating condition) has maintained decomposition rates low at Tannersville Bog. Maybe both high production and low decomposition would explain the pattern best. More studies are needed on the same type of peatland to better understand the environmental controls on peat accumulation.

The dry event inferred by the decline of brown mosses and increase in fine organic debris from 5 to 2.7 ka suggest that the decline of hemlock pollen from 5.5-3 ka at Tannersville Bog might have been driven by a dry climate in North America, as documented elsewhere. The transition from a brown moss-dominated rich fen to a sedge and *Sphagnum*-dominated poor fen at Tannersville Bog at ~1.4 ka was characterized by i) increased organic matter content and decrease in diatoms; ii) low water table and high decomposition rates as inferred by testate amoebae and humification data; and iii) decrease in groundwater input suggested by low carbonate content. The timing of the transition is coincident with a low lake level event and a dry climate at nearby White Lake in northeastern New Jersey at ~1.3 ka (Li et al. 2007).

The high primary production at Tannersville Bog is likely due to the warmer and wetter climate in temperate regions compared to boreal regions, despite the possibilities of higher decomposition under a warmer climate and other possible environmental factors. This study implies that some types of northern peatlands can behave as carbon sinks under a warmer and wetter climate in the future. Based on observation and climatic modeling, projected warming in the 21st century is expected to be greatest at most high northern latitudes, and the increases in the amount of precipitation are very likely in high-latitudes (IPCC 2007 Synthesis Report). Under this scenario, northern peatlands that are similar to the carbon accumulation at Tannersville Bog are expected to behave as carbon sinks.

7 References

Asada, T., Warner, B. G. and Schiff, S. L. 2005. Effects of shallow flooding on vegetation and carbon pools in boreal peatlands. *Applied Vegetation Science* 8, 199-208.

Barber, K. E., Chambers, F. M., Maddy, D., Stoneman, R. and Brew, J. S. 1994. A sensitive high resolution record of late Holocene climatic change from a raised bog in northern England. *The Holocene* 4, 198-205.

Belyea, L. R. and Baird, A. J. 2006. Beyond "The limits to peat bog growth": Cross-scale feedback in peatland development. *Ecological Monographs* 76, 299-322.

Belyea, L. R. and Malmer, N. 2004. Carbon sequestration in peatland: patterns and mechanisms of response to climate change. *Global Change Biology* 10, 1043-1052.

Berger, A. 1978. Long-term variations of daily insolation and Quaternary climatic changes. *Journal of Atmospheric Science* 35, 2362-2367.

Bond, G. C., Kromer, B., Beer, J., Muscheler, R., Evans, M. N., Showers, W., Hoffmann, S., Lotti-Bond, R., Hajdas, I. and Bonani, G. 2001. Persistent solar influence on North Atlantic climate during the Holocene. *Science* 294, 2130-2136.

Booth, R. K. 2002. Testate amoebae as paleoindicators of surface-moisture changes on Michigan peatlands: modern ecology and hydrological calibration. *Journal of Paleolimnology* 28, 329-348.

Booth, R. K. 2007. Testate amoebae as paleoindicators of surface-moisture changes on Michigan peatlands: modern ecology and hydrological calibration. *Journal of Paleolimnology* 28, 329-348.

Booth, R. K. 2008. Testate amoebae as proxies for mean annual waiter-table depth in *Sphagnum*-dominated peatlands of North America. *Journal of Quaternary Science* 23, 43-57.

Booth, R. K. and Jackson, S. T. 2003. A high-resolution record of late-Holocene moisture variability from a Michigan raised bog, USA. *The Holocene* 13, 863-876.

Booth, R. K., Jackson, S. T. and Gray, C. E. D. 2004. Paleoecology and high-resolution paleohydrology of a kettle peatland in upper Michigan. *Quaternary Research* 61, 1-13.

Borren, W., Bleuten, W. and Lapshina, E. D. 2004. Holocene peat and carbon accumulation rates in the southern taiga of western Siberia. *Quaternary Research* 61, 42-51.

Botch, M. S., Kobak, K. I., Vinson, T. S. and Kolchugina, T. P. 1995. Carbon pools and accumulation in peatlands of the former Soviet Union. *Global Biogeochemical Cycles* 9, 37-46.

Bunting, M. J., Morgan, C. R., Van Bakel, M. and Warner, B. G. 1998. Pre-European settlement conditions and human disturbance of a coniferous swamp in southern Ontario. *Canadian Journal of Botany* 76, 1770-1779.

Campbell, D. R., Duthie, H. C. and Warner, B. G. 1997. Post-glacial development of a kettle-hole peatland in southern Ontariò. *Ecoscience* 4, 404-418.

Carroll, P. and Crill, P. 1997. Carbon balance of a temperate poor fen. *Global Biogeochemical Cycles* 11, 349-356.

Caseldine, C. J., Baker, A., Charman, D. J. and Hendon, D. 2000. A comparative study of optical properties of NaOH peat extracts: implication for humification studies. *The Holocene* 10, 649-658.

Charman, D. J., Aravena, R. and Warner, B. G. 1994. Carbon Dynamics in a Forested Peatland in North-Eastern Ontario, Canada. *Journal of Ecology* 82, 55-62.

Charman, D. J., Brown, A. D., Hendon, D. and Karofeld, E. 2004. Testing the relationship between Holocene peatland palaeoclimate reconstructions and instrumental data at two European sites. *Quaternary Science Reviews* 23, 137-143.

Charman, D. J., Hendon, D. and Packman, S. 1999. Multiproxy surface wetness records from replicate cores on an ombrotrophic mire: implications for Holocene palaeoclimate records. *Journal of Quaternary Science* 14, 451-463.

Charman, D. J., Hendon, D. and Woodland, W. A. 2000: *The identification of Testate Amoebae (Protozoa: Rhizopoda) in peats.* London, Frontier Print and Design.

Clymo, R. S. 1984. The limits to peat bog growth. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences* 303, 605-654.

Clymo, R. S., Turunen, J. and Tolonen, K. 1998. Carbon accumulation in peatland. *Oikos* 81, 368-388.

COHMAP. 1988. Climatic changes of the last 18,000 years: observations and model simulations. *Science* 241, 1043-1052.

Cushing, C. E. and Allan, J. D. 2001: *Streams, their ecology and life.* Hong Kong, Academic Press. pp 366.

Davidson, E. A. and Janssens, I. A. 2006. Temperature sensitivity of soil carbon decomposition and feedbacks to climate change. *Nature* 440, 165-173.

Dean, W. E. J. 1974. Determination of carbonate and organic matter in calcareous sediments and sedimentary rocks by loss on ignition: comparison with other methods. . *Journal of Sedimentary Petrology* 44, 242-248.

Deevey, E. S. 1939. Studies on Connecticut lake sediments. I. A postglacial climatic chronology for southern New England. *American Journal of Science* 237, 691-724.

Dickinson, C. H. 1983: Micro-organisms in peatlands. *Ecosystems of the World,* General studies ed. Amsterdam, Elsevier. 4A, 225-245.

Fægri, K. and Iversen, J. 1989: *Textbook of pollen analysis.* London, Wiley. pp 328.

Fisher, D. A., Koerner, R. M. and Reeh, N. 1995. Holocene climatic records from Agassiz Ice Cap, Ellesmere Island, NWT, Canada. *The Holocene* 5, 19-24.

Foster, D. R. 1984. The dynamics of *Sphagnum* in forest and peatland communities in southeastern Labrador, Canada. *Arctic* 37, 133-140.

Foster, D. R., Oswald, W. W., Faison, E. K., Doughty, E. D. and Hansen, B. C. S. 2006. A climatic driver for abrupt mid-Holocene vegetation dynamics and the hemlock decline in New England. *Ecology* 87, 2959-2966.

Frolking, S., Roulet, N. and Fuglestvedt, J. 2006. How northern peatlands influence the Earth's radiative budget: Sustained methane emission versus sustained carbon sequestration. *Journal of Geophysical Research-Biogeosciences* 111, G01008, doi:10.1029/2005JG000091.

Frolking, S., Roulet, N. T., Moore, T. R., Richard, P. J. H., Lavoie, M. and Muller, S. D.

2001. Modeling northern peatland decomposition and peat accumulation. *Ecosystems* 4, 479-498.

Gehris, C. W. 1964: Pollen analysis of the Cranberry Bog Preserve, Tannersville, Monroe County, Pennsylvania. Ph.D. Dissertation. Pennsylvania State University, State College, Pennsylvania, USA.

Gorham, E. 1991. Northern peatlands: role in the carbon cycle and probable responses to climatic warming. *Ecological Applications* 1, 182-195.

Gorham, E., Janssens, J. A. and Glaser, P. H. 2003. Rates of peat accumulation during the postglacial period in 32 sites from Alaska to Newfoundland, with special emphasis on northern Minnesota. *Canadian Journal of Botany* 81, 429-438.

Grimm, E. C. 1987. CONISS - a Fortran-77 program for stratigraphically constrained cluster-analysis by the method of incremental sum of squares. *Computers & Geosciences* 13, 13-35.

Haug, G. H., Hughen, K. A., Sigman, D. M., Peterson, L. C. and Rohl, U. 2001. Southward migration of the intertropical convergence zone through the Holocene. *Science* 293, 1304-1308.

Heal, O. W., Latter, P. M. and Howson, G. 1978: A study of the rates of decomposition of organic matter. In O. W. Heal and D. F. Perkins, editor, *Production Ecology of British Moors and Montane Grasslands,* New York, Springer. 136-159.

Heiri, O., Lotter, A. F. and Lemcke, G. 2001. Loss on ignition as a method for estimating organic and carbonate content in sediments: reproducibility and comparability of results. *Journal of Paleolimnology* 25, 101-110.

Hirsch, A. M. 1977. Geology of the Tannersville Bog study area, Monroe County, Pennsylvania. The Nautre Conservancy Report. Jack McCormick & Associates Inc., Boston. pp 65.

Huber, U. M. and Markgraf, V. 2003. European impact on fire regimes and vegetation dynamics at the steppe-forest ecotone of southern Patagonia. *The Holocene* 13, 567-579.

Ingram, H. A. P. 1982. Size and shape in raised mire ecosystems: a geophysical model. *Nature* 297, 300-303.

Ingram, H. A. P. 1983: Hydrology. In A. J. P. Gore, editor, *Ecosystems of the World*, Elsevier. 4A, 67-185.

Jenny, H., Gessel, S. and Bingham, F. T. 1949. Comparative study of decomposition rates of organic matter in temperate and tropical regions. *Soil Science* 68, 419-432.

Johnsen, S. J., DahlJensen, D., Gundestrup, N., Steffensen, J. P., Clausen, H. B., Miller, H., Masson-Delmotte, V., Sveinbjornsdottir, A. E. and White, J. 2001. Oxygen isotope and palaeotemperature records from six Greenland ice-core stations: Camp Century, Dye-3, GRIP, GISP2, Renland and NorthGRIP. *Journal of Quaternary Science* 16, 299-307.

Kuhry, P. and Vitt, D. H. 1996. Fossil carbon/nitrogen ratios as a measure of peat decomposition. *Ecology* 77, 271-275.

Lamentowicz, M., Tobolski, K. and Mitchell, E. A. D. 2007. Palaeoecological evidence for anthropogenic acidification of a kettle-hole peatland in northern Poland. *The Holocene* 17, 1185-1196.

Langdon, P. G. and Barber, K. E. 2005. The climate of Scotland over the last 5000 years inferred from multiproxy peatland records: inter-site correlations and regional variability. *Journal of Quaternary Science* 20, 549-566.

Le´vesque, P. E. M., Dinel, H. and Larouche, A. 1988: *Guide to the identification of plant macrofossils in Canadian peatlands.* Ontario, Land Resource Research Centre Ottawa. Publication no. 1817. pp 55.

Li, Y., Yu, Z. and Kodama, K. P. 2007. Sensitive moisture response to Holocene millennial-scale climate variations in the Mid-Atlantic region, USA. *The Holocene* 17, 3-8.

Luebbe, A. J. 2007: Hydrology and dissolved organic carbon dynamics of a temperate peatland. M.Sc. Thesis. Lehigh University, Bethlehem, PA.

Maimer, N., Svensson, B. M. and Wallen, B. 1994. Folia Geobot. *Phytotaxon* 29, 483-496.

Makila, M. 1997. Holocene lateral expansion, peat growth and carbon accumulation on Haukkasuo, a raised bog in southeastern Finland. *Boreas* 26, 1-14.

Makila, M., Saarnisto, M. and Kankainen, T. 2001. Aapa mires as a carbon sink and source during the Holocene. *Journal of Ecology* 89, 589-599.

Malmer, N. and Holm, E. 1984. Variation in the C/N-quotient of peat in relation to decomposition rate and age determination with ^{210}Pb. *Oikos* 43, 171-182.

McAndrews, J. H., Berti, A. A. and Norris, G. 1973: *Key to the Quaternary pollen and spores of the Great Lakes region.* Toronto, Ontario, Royal Ontario Museum Life Sciences Miscellaneous Publication. pp 61.

Mitsch, W. and Gosselink, J. G. 2000: *Wetlands.* New York, John Wiley & Sons, Inc.

Ovenden, L. 1990. Peat accumulation in northern wetlands. *Quaternary Research* 33, 377-386.

Page, S. E., Wust, R. A. J., Weiss, D., Rieley, J. O., Shotyk, W. and Limin, S. H. 2004. A record of Late Pleistocene and Holocene carbon accumulation and climate change from an equatorial peat bog (Kalimantan, Indonesia): implications for past, present and future carbon dynamics. *Journal of Quaternary Science* 19, 625-635.

Reimer, P. J., Baillie, M. G. L., Bard, E., Bayliss, A., Beck, J. W., Bertrand, C. J. H., Blackwell, P. G., Buck, C. E., Burr, G. S., Cutler, K. B., Damon, P. E., Edwards, R. L., Fairbanks, R. G., Friedrich, M., Guilderson, T. P., Hogg, A. G., Hughen, K. A., Kromer, B., McCormac, F. G., Manning, S. W., Ramsey, C. B., Reimer, R. W., Remmele, S., Southon, J. R., Stuiver, M., Talamo, S., Taylor, F. W., van der Plicht, J. and Weyhenmeyer, C. E. 2004. IntCal04 Terrestrial radiocarbon age calibration, 26 - 0 ka BP. *Radiocarbon* 46, 1029-1058.

Ritchie, J. C., Cwynar, L. C. and Spear, R. W. 1983. Evidence from northwest Canada for an early Holocene Milankovitch Thermal Maximum. *Nature* 305, 126-128.

Roulet, N. T., Lafleur, P. M., Richard, P. J. H., Moore, T. R., Humphreys, E. R. and Bubier, J. 2007. Contemporary carbon balance and late Holocene carbon accumulation in a northern peatland. *Global Change Biology* 13, 397-411.

Russell, E. W. B. 1980. Vegetational change in northern New Jersey from precolonization to the present: a palynological interpretation. *Bulletin of The Torrey Botanical Club* 107, 432-446.

Rydin, H., Gunnarsson, U. and Sundberg, S. 2006: The role of *Sphagnum* in peatland development and persistence. In R. K. Wieder and D. H. Vitt, editor, *Boreal Peatland Ecosystems*, Springer. Ecological Studies, 188, 47-65.

Rydin, H. and Jeglum, J. 2006: *The Biology of Peatlands.* New York, Oxford University Press. pp 343.

Shuman, B. and Donnelly, J. P. 2006. The influence of seasonal precipitation and temperature regimes on lake levels in the northeastern United States during the Holocene. *Quaternary Research* 65, 44-56.

Smol, J. P. 1990: Freshwater Algae. In B. G. Warner, editor, *Methods in Quaternary Ecology,* Stittsville, Love Printing Service Ltd., 3-14.

Sousa, V. 2008: Drought, lake-effect snow, and the late Holocene beech decline: a paleoecological study at Pinhook Peatland in northwestern Indiana. M.Sc. Thesis. Lehigh University, Bethlehem, PA.

Stuiver, M., Reimer, P. J., Bard, E., Beck, J. W., Burr, G. S., Hughen, K. A., Kromer, B., McCormac, F. G., v. d. Plicht, J. and Spurk, M. 1998. INTCAL98 Radiocarbon age calibration 24,000 - 0 cal BP. *Radiocarbon* 40, 1041-1083.

Tansley, A. G. 1939: *The British Islands and their Vegetation.* Cambridge, Cambridge University Press. pp 484.

Tolonen, K. and Turunen, J. 1996. Accumulation rates of carbon in mires in Finland and implications for climate change. *The Holocene* 6, 171-178.

van Breemen, N. 1995. How *Sphagnum* bogs down other plants. *Trends in Ecology & Evolution* 10, 270-275.

Vardy, S. R., Warner, B. G., Turunen, J. and Aravena, R. 2000. Carbon accumulation in permafrost peatlands in the Northwest Territories and Nunavut, Canada. *The Holocene* 10, 273-280.

Vasander, H. and Kettunen, A. 2006: Carbon in boreal peatlands. In R. K. Wieder and D. H. Vitt, editor, *Boreal Peatland Ecosystems*, Springer. Ecological Studies, 188, 165-194.

Verhoeven, J. T. A. and Liefveld, W. M. 1997. The ecological significance of organochemical compounds in *Sphagnum*. *Acta Botanica Neerlandica* 46, 117-130.

Vitt, D. H. 2006: Functional characteristics and indicators of boreal peatlands. In R. K. Wieder and D. H. Vitt, editor, *Boreal Peatland Ecosystems*, Springer Berlin Heidelberg. Ecological Studies, 188, 9-24.

Vitt, D. H., Halsey, L. A., Bauer, I. E. and Campbell, C. 2000. Spatial and temporal trends in carbon storage of peatlands of continental western Canada through the Holocene. *Canadian Journal of Earth Sciences* 37, 683-693.

Walker, D. 1970: Direction and rate in some British post-glacial hydrosers. In D. Walker and R. G. West, editor, *Studies in the Vegetation History of the British Isles,* Cambridge, Cambridge University Press. 43-57.

Walter, H. 1997. The oligotrophic peatlands of Western Siberia - the largest peino-helobiome in the world. *Vegetatio* 34, 167-178.

Warner, B. G., Clymo, R. S. and Tolonen, K. 1993. Implications of peat accumulation at Point Escuminac, New Brunswick. *Quaternary Research* 39, 245-248.

Watts, W. A. 1979. Late Quaternary vegetation of central Appalachia and the New Jersey coastal plain. *Ecological Monographs* 49, 427-469.

Wieder, R. K., Vitt, D. H. and Benscoter, B. W. 2006: Peatlands and the boreal forest. In R. K. Wieder and D. H. Vitt, editor, *Boreal Peatland Ecosystems*, Springer Berlin Heidelberg. Ecological Studies, 188, 1-8.

Willard, D. A., Cronin, T. M. and Verardo, S. 2003. Late-Holocene climate and ecosystem history from Chesapeake Bay sediment cores, USA. *The Holocene* 13, 201-214.

Woodland, W. A., Charman, D. J. and Sims, P. C. 1998. Quantitative estimates of water tables and soil moisture in Holocene peatlands from testate amoebae. *The Holocene* 8, 261-273.

Wright, H. E. J., Mann, D. H. and Glaser, P. H. 1984. Piston corers for peat and lake sediments. *Ecology* 65, 657-659.

Yu, Z. C., Campbell, I. D., Vitt, D. H. and Apps, M. J. 2001a. Modelling long-term peatland dynamics. I. Concepts, review, and proposed design. *Ecological Modelling* 145, 197-210.

Yu, Z. C., McAndrews, J. H. and Eicher, U. 1997. Middle Holocene dry climate caused by change in atmospheric circulation patterns: evidence from lake levels and stable isotopes. *Geology* 25, 251-254.

Yu, Z. C., Turetsky, M. R., Campbell, I. D. and Vitt, D. H. 2001b. Modelling long-term peatland dynamics. II. Processes and rates as inferred from litter and peat-core data. *Ecological Modelling* 145, 159-173.

Yu, Z. C., Vitt, D. H., Campbell, I. D. and Apps, M. J. 2003. Understanding Holocene peat accumulation pattern of continental fens in western Canada. *Canadian Journal of Botany* 81, 267-282.

Appendixes

1. Loss-on-ignition analysis results of core TB07-1

Depth (cm)	H2O %	LOI@550%	Dry Bulk Density (g/cm^3)	CaCO3 %	Silicates %	Ash-free Bulk Density (g/cm^3)
0	95.84	99.03	0.066	0.00	0.97	0.066
2	93.45	97.56	0.070	0.69	1.74	0.069
4	93.94	98.24	0.049	0.33	1.43	0.048
6	93.93	97.19	0.061	0.53	2.28	0.059
8	94.11	97.69	0.056	0.00	2.31	0.054
10	94.04	96.97	0.066	0.00	3.03	0.064
12	94.08	96.93	0.077	0.00	3.07	0.074
14	93.51	96.63	0.081	0.81	2.56	0.078
16	93.09	97.00	0.074	0.66	2.34	0.072
18	91.78	96.84	0.075	0.00	3.16	0.072
20	93.35	94.43	0.068	1.19	4.37	0.064
22	93.34	95.49	0.082	0.79	3.72	0.079
24	91.36	95.36	0.091	1.61	3.03	0.087
26	91.87	94.20	0.101	2.09	3.71	0.095
28	92.60	95.12	0.078	2.51	2.37	0.074
30	92.93	95.41	0.070	1.62	2.97	0.067
32	94.16	94.67	0.059	2.75	2.57	0.056
34	92.61	94.41	0.087	2.62	2.97	0.082
36	93.16	95.35	0.063	2.84	1.81	0.060
38	91.46	97.40	0.080	1.43	1.17	0.078
40	91.17	95.22	0.120	1.63	3.15	0.114
42	91.64	94.12	0.092	2.81	3.06	0.087
44	92.26	95.35	0.089	2.37	2.28	0.085
46	91.13	94.93	0.101	2.56	2.51	0.096
48	90.93	95.54	0.112	3.05	1.42	0.107
50	90.98	95.69	0.113	2.31	2.00	0.108
52	90.66	95.75	0.101	2.58	1.67	0.097
54	90.93	97.07	0.078	1.87	1.06	0.076
56	91.15	96.82	0.092	2.47	0.71	0.089
58	91.40	96.52	0.101	2.26	1.22	0.097
60	93.13	96.23	0.068	1.90	1.86	0.066
62	92.03	97.09	0.088	2.20	0.70	0.086
64	92.20	96.56	0.083	2.35	1.09	0.080
66	93.36	97.60	0.062	2.60	-0.20	0.061
68	93.20	97.29	0.069	1.89	0.81	0.067
70	92.92	97.97	0.077	1.26	0.77	0.076
72	91.39	97.27	0.084	1.55	1.18	0.082
74	92.01	96.15	0.093	1.75	2.10	0.089
76	90.38	96.40	0.101	1.45	2.16	0.097
78	90.63	96.29	0.100	1.14	2.58	0.096
80	90.85	98.26	0.107	1.06	0.67	0.105
82	91.63	98.61	0.087	0.75	0.65	0.086
84	92.62	98.12	0.091	1.07	0.81	0.089
86	91.80	96.14	0.093	1.40	2.45	0.089
88	89.23	94.49	0.122	1.33	4.17	0.115
90	88.55	93.65	0.118	1.24	5.11	0.111
92	90.19	95.25	0.086	1.14	3.62	0.082
94	88.73	93.38	0.114	1.70	4.91	0.107
96	90.40	96.37	0.108	1.35	2.28	0.104
98	89.01	95.19	0.114	1.71	3.11	0.109
100	90.35	95.50	0.108	1.20	3.30	0.103

102	89.45	95.36	0.102	1.28	3.36	0.097
104	90.00	96.85	0.095	1.71	1.45	0.092
106	90.28	94.96	0.089	2.55	2.50	0.085
108	90.67	96.14	0.098	0.50	3.36	0.094
110	91.15	95.48	0.104	0.93	3.59	0.100
112	91.64	96.87	0.089	0.73	2.40	0.086
114	91.64	96.29	0.091	0.54	3.17	0.087
116	92.26	97.04	0.075	1.30	1.66	0.073
118	91.99	96.78	0.080	2.44	0.78	0.077
120	92.62	96.56	0.087	0.93	2.51	0.084
122	92.23	97.11	0.086	1.13	1.76	0.084
124	91.83	96.66	0.100	0.97	2.37	0.097
126	90.92	97.33	0.088	1.29	1.38	0.086
128	91.53	97.23	0.085	0.19	2.58	0.083
130	91.74	97.57	0.088	1.29	1.14	0.086
132	91.62	97.23	0.090	1.08	1.69	0.088
134	91.13	97.61	0.105	0.47	1.92	0.102
136	91.43	97.73	0.076	1.07	1.19	0.074
138	92.04	98.09	0.086	1.88	0.02	0.085
140	92.80	96.46	0.089	0.91	2.63	0.086
142	92.67	97.39	0.090	0.72	1.89	0.088
144	92.26	97.31	0.093	1.75	0.94	0.091
146	91.53	97.08	0.095	1.53	1.39	0.093
148	90.52	96.78	0.104	1.87	1.35	0.101
150	92.33	96.19	0.112	0.87	2.95	0.108
152	91.38	97.24	0.096	2.21	0.56	0.093
154	91.83	97.67	0.089	0.55	1.79	0.087
156	91.70	97.38	0.096	0.68	1.94	0.093
158	91.92	97.70	0.084	0.78	1.53	0.082
160	92.05	94.78	0.094	1.03	4.19	0.089
162	91.99	97.24	0.098	0.66	2.10	0.096
164	92.09	97.58	0.080	0.61	1.81	0.078
166	91.56	97.05	0.092	1.06	1.89	0.089
168	92.14	97.11	0.106	0.76	2.12	0.103
170	91.75	95.06	0.113	1.01	3.93	0.107
172	92.51	97.47	0.085	0.77	1.76	0.083
174	93.14	97.17	0.088	3.68	-0.85	0.086
176	92.20	97.15	0.093	2.98	-0.13	0.090
178	91.71	96.50	0.092	1.95	1.55	0.089
180	91.87	95.03	0.101	1.29	3.68	0.096
182	91.93	96.15	0.095	2.23	1.62	0.091
184	93.42	96.19	0.073	2.00	1.81	0.070
186	93.52	95.76	0.074	2.63	1.61	0.071
188	93.48	95.93	0.072	3.38	0.68	0.069
190	93.41	95.25	0.083	3.34	1.41	0.079
192	92.67	96.12	0.085	3.07	0.81	0.081
194	92.80	95.78	0.078	3.34	0.88	0.075
196	92.81	96.63	0.078	3.11	0.26	0.076
198	91.93	96.29	0.102	2.71	1.00	0.098
200	92.10	95.93	0.095	1.20	2.87	0.091
202	91.54	95.96	0.097	0.33	3.70	0.093
204	92.28	96.33	0.093	0.00	3.67	0.090
206	93.12	97.44	0.092	0.00	2.56	0.090
208	92.65	96.72	0.092	0.00	3.28	0.089
210	93.43	96.23	0.081	2.19	1.58	0.078
212	93.04	97.08	0.088	0.00	2.92	0.086
214	92.39	96.85	0.084	0.39	2.77	0.081
216	93.36	96.08	0.086	0.38	3.54	0.082

218	93.72	97.74	0.076	0.00	2.26	0.074
220	94.50	96.80	0.060	2.16	1.04	0.058
222	93.54	97.70	0.078	1.25	1.04	0.076
224	93.91	96.45	0.066	0.49	3.06	0.064
226	94.47	96.56	0.062	0.26	3.18	0.060
228	93.83	96.35	0.073	0.00	3.65	0.070
230	93.14	95.35	0.088	1.30	3.35	0.084
232	93.33	96.32	0.089	0.00	3.68	0.086
234	93.64	95.72	0.073	0.22	4.06	0.070
236	92.87	95.30	0.087	0.19	4.51	0.083
238	94.14	88.73	0.069	0.24	11.04	0.061
240	94.18	84.42	0.063	2.82	12.75	0.053
242	93.90	79.04	0.071	0.68	20.28	0.056
244	93.89	79.38	0.071	1.14	19.48	0.056
246	92.90	65.20	0.084	3.28	31.52	0.055
248	93.16	65.64	0.079	3.72	30.64	0.052
250	93.03	64.21	0.079	4.34	31.45	0.051
252	92.73	63.58	0.086	4.33	32.09	0.055
254	92.73	64.36	0.087	4.32	31.33	0.056
256	92.85	62.50	0.082	4.57	32.93	0.051
258	91.54	55.31	0.107	5.16	39.52	0.059
260	91.71	56.11	0.066	8.36	35.53	0.037
262	91.94	64.01	0.097	4.87	31.12	0.062
264	91.89	60.30	0.094	4.32	35.37	0.057
266	92.01	61.04	0.098	4.65	34.31	0.060
268	91.61	60.23	0.091	5.15	34.61	0.055
270	91.88	60.74	0.077	7.16	32.10	0.047
272	91.56	64.29	0.097	5.85	29.86	0.063
274	92.86	67.04	0.084	4.08	28.89	0.056
276	92.35	56.00	0.081	5.41	38.59	0.045
278	92.09	58.95	0.090	5.43	35.62	0.053
280	91.63	58.26	0.094	8.66	33.08	0.055
282	92.72	57.87	0.096	6.10	36.03	0.055
284	91.81	55.98	0.094	6.75	37.27	0.053
286	91.51	57.74	0.105	6.49	35.77	0.061
288	91.82	55.90	0.103	7.74	36.36	0.058
290	92.40	59.66	0.104	7.97	32.37	0.062
292	91.85	57.46	0.096	6.96	35.58	0.055
294	92.04	55.64	0.101	7.54	36.82	0.056
296	91.68	53.58	0.112	7.56	38.86	0.060
298	92.15	54.70	0.095	7.69	37.62	0.052
300	91.92	52.03	0.100	8.09	39.88	0.052
302	91.78	53.74	0.099	8.17	38.10	0.053
304	91.50	53.67	0.109	7.31	39.01	0.058
306	91.77	54.31	0.109	7.48	38.22	0.059
308	91.60	54.28	0.102	6.87	38.85	0.055
310	91.45	56.09	0.094	5.16	38.74	0.053
312	91.55	55.95	0.102	6.72	37.33	0.057
314	91.46	54.43	0.106	7.48	38.09	0.058
316	91.69	54.71	0.112	6.95	38.33	0.061
318	91.28	57.18	0.097	7.17	35.65	0.056
320	91.47	57.47	0.088	5.01	37.52	0.050
322	91.74	75.31	0.100	11.92	12.78	0.075
324	91.58	54.86	0.109	7.76	37.39	0.060
326	91.42	56.44	0.106	7.36	36.20	0.060
328	91.74	53.86	0.104	7.99	38.16	0.056
330	91.57	55.88	0.092	5.10	39.01	0.052
332	91.42	54.69	0.110	7.71	37.60	0.060

334	91.27	54.77	0.098	8.61	36.62	0.054
336	91.29	54.17	0.110	8.60	37.23	0.059
338	91.14	53.30	0.108	8.26	38.44	0.058
340	91.03	55.13	0.090	5.03	39.84	0.050
342	91.14	50.98	0.106	8.61	40.41	0.054
344	91.35	51.45	0.113	8.61	39.93	0.058
346	91.34	50.49	0.102	9.20	40.31	0.052
348	91.21	51.89	0.111	8.03	40.07	0.058
350	91.66	53.52	0.102	8.09	38.38	0.055
352	91.58	53.76	0.105	7.92	38.32	0.056
354	91.44	54.59	0.111	7.16	38.25	0.061
356	91.67	56.22	0.101	8.52	35.25	0.057
358	91.38	56.16	0.109	8.49	35.35	0.061
360	91.43	55.24	0.082	6.16	38.59	0.045
362	91.70	55.02	0.095	7.67	37.31	0.052
364	91.44	54.02	0.104	7.97	38.01	0.056
366	91.76	54.34	0.090	8.70	36.96	0.049
368	91.42	53.77	0.106	7.97	38.26	0.057
370	91.45	52.89	0.109	6.58	40.52	0.057
372	91.15	52.97	0.105	8.55	38.48	0.055
374	91.28	66.93	0.099	7.70	25.37	0.066
376	91.96	64.31	0.096	8.13	27.56	0.062
378	91.18	53.53	0.111	9.62	36.85	0.060
380	91.92	52.31	0.096	9.81	37.88	0.050
382	91.06	52.72	0.110	9.56	37.72	0.058
384	91.70	52.22	0.111	9.21	38.57	0.058
386	91.11	52.60	0.109	9.42	37.98	0.057
388	91.61	54.05	0.110	8.68	37.27	0.060
390	91.96	54.10	0.096	9.49	36.41	0.052
392	92.01	54.80	0.101	8.51	36.69	0.055
394	92.25	58.63	0.092	8.66	32.70	0.054
396	92.38	58.85	0.097	9.06	32.09	0.057
398	92.83	61.74	0.098	9.15	29.11	0.060
400	92.02	61.05	0.091	5.35	33.60	0.056
410	92.43	67.85	0.075	3.48	28.67	0.051
420	92.22	64.02	0.073	4.68	31.30	0.047
430	92.13	65.56	0.073	4.42	30.01	0.048
440	92.44	66.50	0.073	2.67	30.82	0.049
450	93.47	68.14	0.074	4.36	27.50	0.051
460	93.24	67.05	0.081	4.43	28.52	0.054
470	91.68	55.40	0.093	6.14	38.46	0.051
480	92.96	55.17	0.067	3.15	41.69	0.037
490	93.06	54.02	0.073	2.68	43.31	0.039
500	92.68	52.93	0.079	2.67	44.40	0.042
510	93.00	51.96	0.084	3.10	44.93	0.044
520	92.38	45.53	0.073	4.65	49.83	0.033
530	92.69	48.33	0.079	4.71	46.96	0.038
540	92.66	48.57	0.070	4.87	46.56	0.034
550	92.19	48.61	0.085	4.22	47.17	0.041
560	92.28	54.58	0.081	3.80	41.62	0.044
570	92.58	54.57	0.084	6.21	39.22	0.046
580	91.91	48.23	0.087	4.87	46.90	0.042
590	91.42	46.66	0.090	5.07	48.27	0.042
600	91.82	49.89	0.098	5.28	44.82	0.049
610	91.25	45.86	0.092	5.28	48.86	0.042
620	91.11	48.14	0.092	5.98	45.87	0.044
630	91.54	52.74	0.098	3.83	43.43	0.052
640	91.00	50.23	0.078	4.35	45.42	0.039

650	91.53	48.44	0.101	5.17	46.39	0.049
660	91.64	47.09	0.087	5.22	47.69	0.041
670	91.43	51.00	0.090	5.44	43.57	0.046
680	91.78	52.57	0.081	5.03	42.40	0.042
690	91.22	52.58	0.101	5.15	42.27	0.053
700	90.27	47.71	0.100	4.72	47.57	0.048
710	89.98	41.01	0.097	5.51	53.48	0.040
720	90.30	42.14	0.102	4.93	52.94	0.043
730	90.01	45.40	0.119	5.06	49.54	0.054
740	89.65	43.04	0.122	4.65	52.30	0.053
750	90.22	48.37	0.101	4.50	47.12	0.049
760	90.54	48.63	0.094	3.63	47.74	0.046
770	91.19	41.35	0.093	5.22	53.43	0.039
780	91.27	44.51	0.096	5.26	50.22	0.043
790	89.96	48.80	0.104	4.70	46.51	0.051
800	90.23	44.35	0.105	5.11	50.54	0.047
810	89.49	46.67	0.106	3.52	49.81	0.050
820	89.69	47.11	0.106	3.67	49.22	0.050
830	89.21	48.56	0.114	4.27	47.17	0.055
840	89.06	46.41	0.104	4.39	49.20	0.048
850	87.33	35.25	0.127	4.62	60.13	0.045
860	87.68	33.81	0.111	5.13	61.06	0.037
870	88.00	36.07	0.113	4.60	59.33	0.041
880	89.39	42.17	0.104	4.71	53.12	0.044
890	87.54	31.44	0.132	5.16	63.40	0.042
900	86.09	30.25	0.147	5.21	64.55	0.044
910	85.27	28.06	0.171	4.85	67.09	0.048
920	83.18	24.73	0.146	4.57	70.70	0.036
930	84.84	26.29	0.155	5.76	67.95	0.041
940	84.29	27.46	0.160	5.89	66.66	0.044
950	85.26	28.81	0.152	6.00	65.19	0.044
960	85.49	27.98	0.172	5.77	66.25	0.048
970	84.03	24.87	0.199	6.13	69.00	0.049
980	83.69	22.39	0.150	6.81	70.81	0.034
990	82.51	22.77	0.196	6.06	71.18	0.045
1000	78.96	19.59	0.197	4.69	75.72	0.039
1010	82.77	24.13	0.159	6.63	69.25	0.038
1020	83.33	25.81	0.150	6.81	67.38	0.039
1030	82.05	24.36	0.174	5.33	70.30	0.042
1040	79.83	18.91	0.196	5.22	75.87	0.037
1050	76.49	18.16	0.209	4.81	77.02	0.038
1060	76.74	18.15	0.224	5.09	76.77	0.041
1070	74.77	15.97	0.271	4.98	79.05	0.043

2. Plant macrofossil percentage data for core TB07-1

Depth (cm)	Detritus	Moss	Sphagnum	Brown moss	Cyperacea	Ligneous	Wood fragments	Picea needle	Larix needle	Leaves	Ericaceae root	Charcoal	Algae	Chitin
0	0		85	0	0	15		15						
2	0	80	80	0	0	20			8	2				
4	0	45	45	0	5	50	45				5			
6	0	80	80	0	0	20	10			5	5			
8	5	50	50	0	0	45	30			10	5			
10	5		60			35	3	2	5	20	5			
12	5	80	80	0	0	15	5			5	5			
14	20	40	40	0	0	40	25	5		10				
16	20	30	30	0	5	45	35			10				
18	20	40	40	0	10	30	25			5				
20	5		60		10	25	4			10	5			
22	20	60	60	0	0	20	20				5			
24	30	50	50	0	0	20	15				5			
26	20	65	65	0	0	15	10				5			
28	20	40	40	0	0	40	40							
30	10		40		40	10				1		8		
32	20	60	60	0	10	10	5				5			
34	10	70	70	0	5	15	10				5			
36	10	60	60	0	10	20	15				5			
38	10	60	60	0	10	20	15				5			
40	15		30		30	25	5			5	5			
42	10	45	45	0	20	25	20				5			
44	10	40	40	0	20	30	20				10			
46	20	20	20	0	20	40	35				5			
48	20	20	20	0	20	40	35				5			
50	15		30		25	30		2	2	2	9			
52	20	20	20	0	30	30	10				20			
54	20	20	20	0	45	15	10				5			
56	10	10	10	0	40	40	40							
58	10	10	10	0	60	20	5				15			
60	20		40	10	20	10			1	2	8			
62	30	20	20	0	30	20	10				10			
64	30	30	30	0	30	10	10							
66	30	30	30	0	30	10	10							
68	30	30	30	0	30	10	10							
70	10		10		75	5	5							

72	20	40	40	0	30	10				10	
74	20	30	30	0	30	20	20				
76	30	10	10	0	40	20	18		2		
78	30	10	10	0	40	20	15			5	
80	20		20	30	25	5	5				
82	20	20	20	0	25	35	30			5	
84	20	10	10	0	50	20	20				
86	20	10	10	0	60	10	10				
88	20	25	25	0	50	5	5				
90	50			20	25	5	2			3	
92	40	5	5	0	25	30	30				
94	40	5	5	0	40	15	15				
96	40	5	5	0	45	10	10				
98	45	5	5	0	40	10	10				
100	50		15		25	10	3	2		5	
102	40	10	10	0	40	10	10				
104	40	5	5	0	25	30	30				
106	50	5	5	0	25	20	10		5	5	
108	50	5	5	0	30	15	10			5	
110	40		15		25	20		2.5	2.5	5	1
112	50	5	5	0	20	25	20			5	
114	50	5	5	0	30	15	10			5	
116	50	5	5	0	30	15	10			5	
118	50	5	5	0	30	15	15				
120	30		10		50	10	5			5	
122	50	5	5	0	30	15	15				
124	50	10	10	0	25	15	15				
126	50	10	10	0	30	10	10				
128	50	10	10	0	30	10	5			5	
130	40		10		40	10	2			3	
132	50	5	5	0	35	10	10				
134	50	10	10	0	30	10	10				
136	50	5	5	0	35	10	10				
138	50	10	5	5	30	10	10				
140	50		10		35	5	5				
142	50	10	10	0	30	10	10				
144	50	10	10	0	30	10	10				
146	50	10	10	0	10	30	20			10	
148	50	10	10	0	20	20	10			10	
150	30		20		40	10	5			5	

152	50	5	5	0	30	15	10			5	
154	50	10	5	5	15	25	20			5	
156	50	5	5	0	35	10	10				
158	50	10	10	0	20	20	10			10	
160	40		20		20	20	5		10	5	
162	40	15	5	10	15	30	10				
164	40	10	5	5	10	40	30			10	
166	50	10	5	5	15	25	20			5	
168	50	15	10	5	15	20	15			5	
170	20		20		50	10	10				
172	50	10	10	0	30	10	5			5	
174	50	15	10	5	30	5	5				
176	40	20	15	5	30	10	10				
178	40	5	5	0	25	30	25			5	
180	20		10		60	10	8	2			
182	50	5	5	0	35	10	5			5	
184	50	20	20	0	25	5	5				
186	50	20	20	0	20	10	10				
188	50	25	25	0	20	5	5				
190	20		30		30	20	15			5	
192	50	15	15	0	25	10	10				
194	50	15	15	0	25	10	10				
196	50	20	20	0	20	10	10				
198	50	30	30	0	15	5	5				
200	60		10		25	5	2			3	
202	60	5	5	0	30	5	5				
204	60	10	10	0	25	5	5				
206	60	5	5	0	30	5	5				
208	60	10	5	5	20	10	10				
210	20		40		20	20	10			5	5
212	60	5	5	0	25	10	5			5	
214	50	10	10	0	30	10	10				
216	60	10	5	5	20	10	5			5	
218	60	5	5	0	25	10	10				
220	20		20		45	15	5		5	5	
222	50	5	5	0	40	5	5				
224	50	10	5	5	30	10	10				
226	50	10	5	5	20	20	20				
228	50	6	3	3	39	5	5				
230	40		15	5	30	10	5			4	

232	50	5	3	2	40	5	5	
234	50	10	5	5	30	10	10	
236	50	15	10	5	25	10	10	
238	50	25	5	20	15	10	5	5
240	40		10	20	20	10	10	
242	50	30	5	25	10	10	10	
244	60	20	10	10	10	10	10	
246	50	25	5	20	10	15	15	
248	60	25	5	20	5	10	10	
250	60	10	0	10	20	10	10	
252	60	15	0	15	10	15	15	
254	50	20	1	19	10	20	5	
256	60	15	0	15	10	15	15	
258	70	10	0	10	10	10	10	
260	60	10		10	10	20	20	
262	60	15	0	15	5	20	20	
264	60	20	0	20	10	10	10	
266	60	20	0	20	10	10	10	
268	60	20	0	20	10	10	10	
270	60	25	0	25	5	10	10	
272	60	25	0	25	5	10	10	
274	60	25	5	20	10	5	5	
276	60	10	0	10	25	5	5	
278	60	20	2	18	15	5	5	
280	60	5	0	5	10	25	5	5
282	60	15	0	15	15	10	10	
284	70	15	0	15	10	5	5	
286	70	15	1	14	10	5	5	
288	70	20	0	20	10	0	0	
290	70	20	1	19	10	0	0	
292	70	15	1	14	5	10	10	
294	70	10	0	10	10	10	10	
296	75	5	0	5	10	10	10	
298	75	10	0	10	15	0	0	
300	60	15	0	15	15	10	10	
302	70	10	0	10	10	10	10	
304	70	15	0	15	15	0	0	
306	70	20	0	20	10	0	0	
308	70	10	1	9	15	5	0	
310	70	10	0	10	15	5	5	

312	80	10	0	10	5	5	5		
314	80	10	0	10	5	5	5		
316	80	5	0	5	10	5	5		
318	80	5	0	5	10	5	5		
320	70	15	5	10	10	5	5		
322	80	5	0	5	10	5	5		
324	80	5	1	4	10	5	5		
326	80	5	0	5	10	5	5		
328	80	12	2	10	8	0	0		
330	85	8	0	8	7	0	0		
332	80	10	0	10	10	0	0		
334	80	10	0	10	10	0	0		
336	85	7	0	7	8	0	0		
338	85	5	0	5	10	0	0		
340	90	5	0	5	5	0	0		5
342	90	5	0	5	5	0	0		
344	90	5	0	5	5	0	0		
346	90	5	0	5	5	0	0		
348	90	5	0	5	5	0	0		
350	90	5	0	5	3	2		2	
352	90	5	0	5	2	3	3		
354	90	2	0	2	3	5		5	
356	90	0	0	0	5	5	2	3	
358	85	8	0	8	7	0	0		
360	90	5	0	5	2	3	1	2	
362	90	5	0	5	5	0	0		
364	85	5	0	5	5	5		5	
366	90	5	2	3	3	2	2		
368	90	2	0	2	3	5	5		
370	90	2	0	2	3	5	5		15
372	90	5	0	5	3	2	2		
374	85	5	0	5	5	5	5		
376	90	2	1	2	3	5	5		
378	90	2	0	2	3	5	5		
380	90	2	0	2	4	4	2	2	10
382	90	2	0	2	3	5	5		
384	90	2	0	2	3	5	5		
386	90	2	0	2	4	4	2	2	
388	95	1	0	1	2	2	2		
390	95	3	0	3	1	1	1		2

392	95	1	0	1	3	1	1				
394	95	1	0	1	2	2	1			1	
396	95	1	0	1	2	2	2				
398	95	2	0	2	2	1	1				
400	95	1	0	1	2	2	1			1	5
410	90			3	3	4	2			2	5
420	90			3	4	3	1			2	
430	90			5	2	3	1			2	5
440	90			5	1	4	1			3	5
450	85			10	2	3	1			2	5
460	85			10	2	3	1			2	3
470	90			5	1	4	2			2	
480	90			5	2	3	1			2	
490	90			4	4	2				2	
500	90			7		3				3	
510	85			5	5	5				5	5
520	90			7		3				3	
530	80			10	5	5	2			3	3
540	80			10	5	5	2			3	5
550	80			12	5	3				3	3
560	80			10	5	5	3			2	3
570	70			20	5	5	2			3	3
580	80			10	5	5	2			3	2
590	70			20	5	5	2			3	2
600	70			20	5	5	3			2	2
610	80			10	2	8	2			6	
620	80			10	2	8	6			2	
630	70			25	2	3	1			2	
640	70			20	5	5	5				
650	80			10	3	7	5			2	
660	80			10	3	7	5			2	
670	80			8	6	6	3			3	
680	80			8	4	8	6			2	
690	80			10	4	6	2			2	
700	80			10	3	7	5			2	
710	80			8	4	8	6			2	
720	80			8	4	8	6			2	
730	80			8	4	8	4			4	
740	80			8	6	6	4			2	
750	85		1	4	5	5	1	2	1	1	

760	80		5	10	5	5			
770	85		2	8	5	3	1	1	
780	90	1		6	3	2		1	
790	90		1	6	3	2		1	
800	90		2	4	4	3		1	
810	90	2		4	4	3		1	
820	95		1	2	2	1		1	
830	95		1	2	2	2			
840	95		2	2	1	1			
850	90		2	4	4	1		3	
860	95	1		2	2	1		1	
870	95	1	1	2	2	1		1	
880	95	1		2	2	1		1	
890	90		1	4	5	5			
900	80		6	2	2	2			10
910	70		5	3	2			2	20
920	70	2			2			2	26
930	80	2		5	8	3		5	5
940	85			6	9	6		3	
950	90			5	5	4		1	
960	95			1	4	3		1	
970	95			2	3	3			
980	95			2	3	2		1	
990	95			2	3	2		1	
1000	98			2					
1010	98			1	1			1	
1020	97			3					
1030	98			2					
1040	96			2	2	1		1	
1050	95			1	4	2		2	
1060	98			1	1	1			
1070	98			0.5	1.5	0.5		1	

3. Humification for core TB07-1 measured in light transmittance (%)

WL (nm)	10 a	10 b	20 a	20 b	30 a	30 b	40 a	40 b	50 a	50 b
400	13	13	16	15	9.3	9.1	9.1	9.2	8.2	8.3
405	14	14	17	17	11	10	11	11	9.5	9.6
410	16	16	19	19	12	12	12	12	11	11
415	17	17	21	21	14	13	14	14	12	12
420	19	19	23	22	15	15	15	16	14	14
425	21	20	25	24	17	17	17	17	16	16
430	22	22	27	26	19	18	19	19	17	17
435	24	24	29	29	21	20	21	21	19	19
440	26	26	31	30	23	22	23	23	21	21
445	28	28	33	32	24	24	24	25	23	23
450	30	30	35	34	26	26	26	26	24	24
455	32	32	37	36	28	28	28	28	26	26
460	34	33	39	38	30	30	30	30	28	28
465	35	35	40	40	32	31	31	32	29	30
470	37	37	42	42	34	33	33	33	31	31
475	39	39	44	44	36	35	35	35	33	33
480	40	40	46	45	37	37	36	36	34	34
485	42	42	47	47	39	39	38	38	36	36
490	43	43	49	48	41	40	39	40	37	38
495	45	45	50	50	43	42	41	41	39	39
500	46	46	52	51	44	44	42	42	40	40
505	48	48	53	53	46	45	44	44	42	42
510	49	49	55	55	48	47	45	46	44	44
515	51	51	57	56	49	49	47	47	45	45
520	53	53	58	58	51	51	49	49	47	47
525	54	54	60	59	53	52	50	51	49	49
530	56	56	62	61	55	54	52	52	51	51
535	58	58	63	63	56	56	54	54	53	53
540	**60**	59	**65**	64	**58**	57	**56**	56	**54**	54
545	61	61	66	66	60	59	57	57	56	56
550	63	62	67	67	61	60	59	59	58	58
555	64	64	69	69	63	62	60	61	59	59
560	66	66	70	70	64	63	62	62	61	61
565	67	67	72	71	66	65	63	64	63	63
570	69	69	73	73	67	66	65	65	64	64
575	71	70	74	74	68	67	66	67	66	66
580	72	72	75	75	69	69	68	68	67	67
585	74	74	77	76	71	70	69	70	69	69
590	75	75	78	77	72	71	71	71	70	70
595	76	76	79	78	73	72	72	72	71	71
600	77	77	80	79	74	73	73	73	72	72
605	79	78	81	80	75	74	74	74	74	74
610	80	79	82	81	76	75	75	75	75	74
615	81	80	82	82	77	76	76	76	75	75
620	81	81	83	83	78	77	77	77	76	76
625	82	82	84	83	79	78	78	78	77	77
630	83	83	85	84	80	79	79	79	78	78
635	84	84	85	85	81	80	80	80	79	79
640	85	84	86	86	81	81	81	81	80	80
645	85	85	87	86	82	82	82	82	81	81
650	86	86	88	87	83	83	82	83	82	82
655	87	87	88	88	84	83	83	84	83	83

WL (nm)	60 a	60 b	70 a	70 b	80 a	80 b	90 a	90 b	100 a	100 b
400	12	12	10	10	14	14	9.5	9.5	6.1	5.7
405	14	14	12	12	16	16	11	11	7.3	6.9
410	16	15	14	14	19	19	13	13	8.7	8.2
415	17	17	15	15	21	21	15	15	10	9.6
420	19	19	17	17	23	23	17	17	12	11
425	21	21	19	19	26	26	18	19	14	13
430	23	23	21	21	28	28	20	21	15	15
435	25	25	23	23	30	30	23	23	17	17
440	27	27	25	25	33	33	25	25	19	18
445	29	29	27	27	35	35	27	27	21	20
450	31	31	29	29	37	37	28	29	23	22
455	33	33	30	30	39	39	30	30	25	24
460	35	34	32	32	41	41	32	32	26	25
465	36	36	34	34	43	43	34	34	28	27
470	38	38	36	35	44	44	36	36	30	29
475	40	39	37	37	46	46	37	38	32	31
480	42	41	38	38	48	48	39	39	33	32
485	43	43	40	39	49	49	41	41	35	34
490	45	44	41	41	51	51	42	43	37	35
495	46	46	42	42	52	52	44	44	38	37
500	47	47	43	43	54	54	45	46	40	38
505	49	49	44	44	55	55	47	47	41	40
510	51	50	45	45	57	57	49	49	43	42
515	52	52	47	47	58	58	51	51	45	44
520	54	53	48	48	60	60	52	53	47	46
525	56	55	50	50	61	61	54	55	49	48
530	57	57	51	51	63	63	56	56	51	49
535	59	58	53	53	64	64	58	58	52	51
540	**61**	60	**55**	54	**66**	66	**59**	60	**54**	53
545	62	61	56	56	67	67	61	61	56	54
550	63	63	58	57	68	68	63	63	57	56
555	65	65	59	59	70	70	64	64	59	58
560	67	66	61	61	71	71	66	66	61	60
565	68	68	63	63	72	72	67	67	62	61
570	69	69	65	65	73	73	68	68	64	63
575	71	71	67	67	75	75	70	70	65	64
580	72	72	69	69	76	76	71	71	67	66
585	74	73	71	70	77	77	72	72	68	67
590	75	75	72	72	78	78	73	74	70	69
595	76	76	74	74	79	79	75	75	71	70
600	77	77	75	75	80	80	76	76	72	71
605	78	78	77	76	81	81	77	77	73	72
610	79	79	78	77	82	82	78	78	74	73
615	80	80	79	78	82	82	78	79	75	74
620	81	81	80	79	83	83	79	79	76	75
625	82	81	81	80	84	84	80	80	77	76
630	83	82	82	81	85	85	81	81	78	77
635	83	83	82	82	85	85	82	82	79	78
640	84	84	83	83	86	86	83	83	80	79
645	85	84	84	84	86	86	83	83	81	79
650	85	85	85	84	87	87	84	84	81	80
655	86	86	85	85	87	87	84	84	82	81

WL (nm)	110 a	110 b	120 a	120 b	130 a	130 b	140 a	140 b	150 a	150 b
400	10	10	7.9	7.8	10	10	13	13	10	10
405	12	12	9.3	9.2	12	12	14	14	12	12
410	14	14	11	11	13	13	16	16	13	13
415	15	15	12	12	15	15	18	18	15	15
420	17	17	14	14	17	17	20	20	17	17
425	19	19	16	16	19	19	22	22	19	18
430	21	21	18	18	21	21	24	24	20	20
435	23	23	20	20	23	23	26	26	22	22
440	25	25	22	21	25	25	28	28	24	24
445	27	27	23	23	27	27	30	30	26	26
450	29	29	25	25	28	28	32	32	28	28
455	31	31	27	27	30	30	34	34	30	29
460	33	33	29	28	32	32	36	36	32	31
465	34	35	30	30	34	34	38	38	33	33
470	36	36	32	32	36	36	39	39	35	35
475	38	38	34	34	38	38	41	41	37	37
480	40	40	36	35	39	39	43	43	39	38
485	41	42	37	37	41	41	45	45	41	40
490	43	43	39	39	43	43	47	46	42	42
495	44	45	40	40	45	45	48	48	44	43
500	46	46	42	42	46	46	50	50	46	45
505	48	48	44	44	48	48	52	52	47	47
510	49	50	46	46	50	50	53	53	49	49
515	51	51	48	47	52	52	55	55	51	51
520	53	53	49	49	54	54	57	57	53	53
525	55	55	52	51	56	56	59	59	55	55
530	56	57	53	53	58	58	60	60	57	56
535	58	58	55	55	59	59	62	62	59	58
540	**60**	60	**57**	57	**61**	61	**64**	64	**60**	60
545	61	61	59	58	63	62	65	65	62	61
550	63	63	60	60	64	64	67	66	63	63
555	64	64	62	62	66	66	68	68	65	65
560	66	66	63	63	67	67	69	69	66	66
565	67	67	65	65	68	68	71	70	68	67
570	68	68	66	66	70	70	72	72	69	69
575	69	70	68	67	71	71	73	73	70	70
580	71	71	69	69	72	72	74	74	72	71
585	72	72	70	70	73	73	75	75	73	72
590	73	73	72	71	74	74	76	76	74	74
595	74	74	73	72	75	75	77	77	75	75
600	75	75	74	73	76	76	78	78	76	76
605	76	77	75	75	77	77	79	79	77	77
610	77	77	76	75	78	78	80	80	78	78
615	78	78	77	76	79	79	81	81	79	79
620	79	79	78	77	80	80	82	81	80	79
625	80	80	79	78	81	81	82	82	81	80
630	81	81	79	79	82	82	83	83	82	81
635	81	82	80	80	82	82	84	84	82	82
640	82	82	81	81	83	83	85	84	83	83
645	83	83	82	81	83	84	85	85	84	83
650	83	84	82	82	84	84	86	86	85	84
655	84	84	83	83	85	85	86	86	85	85

WL (nm)	160 a	160 b	170 a	170 b	180 a	180 b	190 a	190 b	200 a	200 b
400	12	11	13	13	13	14	8.6	8.6	9.7	9.8
405	13	13	15	15	15	15	10	10	11	11
410	15	15	17	16	17	17	11	11	13	13
415	17	16	18	18	19	19	13	13	15	15
420	18	18	20	20	21	21	15	15	16	17
425	20	20	22	22	23	23	16	16	18	18
430	22	22	24	24	25	26	18	18	20	20
435	24	24	26	26	27	28	20	20	22	22
440	26	26	28	28	29	30	22	22	24	24
445	28	28	30	29	31	32	23	23	25	26
450	30	29	32	31	33	33	25	25	27	27
455	32	31	33	33	35	35	27	27	29	29
460	33	33	35	35	37	37	29	29	31	31
465	35	35	37	36	39	39	30	30	32	33
470	37	37	39	38	41	41	32	32	34	34
475	39	38	40	40	42	42	34	34	36	36
480	41	40	42	41	44	44	35	35	38	38
485	42	42	43	43	46	46	37	37	39	40
490	44	44	45	44	47	48	39	39	41	41
495	46	45	46	46	49	49	40	40	42	43
500	47	47	48	47	51	51	42	42	44	45
505	49	49	50	49	52	53	44	44	46	46
510	51	51	51	51	54	54	45	45	48	48
515	53	52	53	53	56	56	47	47	50	50
520	55	54	55	54	57	57	49	49	51	52
525	57	56	57	56	59	59	51	51	53	54
530	58	58	58	58	60	61	53	53	55	56
535	60	59	60	60	62	62	55	55	57	57
540	**62**	61	**62**	61	**64**	64	**57**	57	**59**	59
545	63	63	63	63	65	65	58	58	60	60
550	65	64	65	64	66	67	60	60	62	62
555	66	66	66	66	68	68	62	62	63	64
560	68	67	68	67	69	69	63	63	65	65
565	69	69	69	69	70	71	65	65	66	66
570	70	70	71	70	71	72	66	66	68	68
575	72	71	72	71	73	73	68	68	69	69
580	73	72	73	73	74	74	69	69	70	70
585	74	73	74	74	75	75	70	70	71	72
590	75	74	75	75	76	76	71	72	72	73
595	76	76	77	76	77	77	73	73	73	74
600	77	76	78	77	78	78	74	74	74	75
605	78	77	79	78	79	79	75	75	76	76
610	79	78	79	79	79	80	76	76	76	77
615	80	79	80	80	80	81	77	77	77	78
620	81	80	81	80	81	81	78	78	78	79
625	82	81	82	81	82	82	79	79	79	80
630	82	82	83	82	83	83	80	80	80	80
635	83	82	84	83	83	84	81	81	81	81
640	84	83	84	84	84	84	81	81	82	82
645	84	84	85	84	85	85	82	82	82	83
650	85	85	86	85	86	86	83	83	83	84
655	86	85	86	86	86	86	84	84	84	84

210		220		230		240		250		260		270		280		290		300		310		320		330		340		350		360		370		380		390		400	
a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b
9.7	9.7	16	16	5.5	5.6	7.4	7.4	10	10	14	14	10	11	16	16	10	9.9	12	11	12	12	15	15	18	18	14	14	14	14	15	15	17	17	19	19	15	15	11	11
11	11	18	18	6.6	6.6	8.5	8.5	12	12	16	16	12	12	18	18	11	11	13	12	13	14	17	17	20	20	16	15	16	15	16	16	18	18	20	21	16	16	12	12
13	13	20	20	7.7	7.8	9.7	9.7	13	13	18	18	13	14	20	19	13	13	15	14	15	15	18	18	22	22	17	17	17	17	18	18	20	20	22	22	18	18	14	14
15	15	22	22	8.9	9	11	11	15	15	20	20	15	15	22	21	15	15	17	16	16	17	20	20	24	24	19	19	19	19	20	20	22	22	24	24	20	20	15	15
16	16	25	24	10	10	13	13	17	17	22	22	17	17	24	23	16	16	18	17	18	19	22	22	26	26	21	21	21	21	22	22	24	24	26	26	22	22	17	17
18	18	27	27	12	12	14	14	18	19	24	24	18	19	26	25	18	18	20	19	20	21	24	24	28	28	23	23	23	23	23	23	26	26	28	28	24	24	19	19
20	20	29	29	13	13	16	16	20	20	26	25	20	21	28	27	20	20	22	21	22	23	26	26	30	30	25	25	25	25	25	25	28	28	30	30	26	26	20	21
22	22	32	31	15	15	17	17	22	22	28	28	22	23	30	30	22	22	24	23	24	25	28	28	32	32	27	27	27	27	27	27	30	30	32	33	28	28	22	23
24	24	34	33	16	16	19	19	24	24	30	29	24	24	32	31	24	24	26	25	26	27	30	30	34	34	29	29	29	29	29	29	32	32	34	34	30	30	24	24
25	25	36	36	18	18	21	21	26	26	31	31	26	26	34	33	26	25	28	27	28	29	32	32	36	36	31	30	31	30	31	31	34	34	36	36	32	31	26	26
27	27	38	38	19	20	22	22	28	28	33	33	27	28	36	35	27	27	30	29	30	31	34	34	38	38	33	32	33	32	33	33	36	36	38	38	33	33	28	28
29	29	40	40	21	21	24	24	29	29	35	35	29	30	38	37	29	29	32	30	32	32	36	36	40	40	34	34	34	34	35	35	38	38	40	40	35	35	29	30
31	31	42	42	23	23	26	26	31	31	37	37	31	32	40	39	31	31	34	32	33	34	38	38	42	42	36	36	36	36	37	37	39	39	42	42	37	37	31	31
32	33	44	43	24	24	27	27	33	33	39	39	33	33	42	41	33	32	35	34	35	36	39	39	43	44	38	38	38	38	38	38	41	41	43	44	39	39	33	33
34	34	46	46	26	26	29	29	35	35	41	41	35	35	44	43	35	34	37	36	37	38	41	41	45	46	40	40	40	39	40	40	43	43	45	45	41	40	35	35
36	36	48	48	28	28	31	31	37	37	43	42	37	37	46	45	37	36	39	38	39	40	43	43	47	47	42	41	42	41	42	42	45	45	47	47	42	42	36	37
38	38	50	49	29	30	33	33	39	39	44	44	39	39	47	47	39	38	41	40	41	41	45	45	49	49	43	43	43	43	44	44	47	47	49	49	44	44	38	38
40	40	52	51	31	32	36	36	41	41	46	46	41	41	50	49	41	41	43	42	43	43	47	47	51	51	45	45	45	45	46	46	49	49	51	51	46	46	40	40
41	41	53	53	33	33	37	38	42	43	48	48	43	43	51	50	43	42	45	44	44	45	48	48	52	53	47	47	47	47	48	48	50	50	52	52	48	48	42	42
43	43	55	55	35	35	40	40	44	44	50	50	45	45	53	52	45	44	47	46	46	47	50	50	54	54	49	49	49	48	49	49	52	52	54	54	50	49	43	44
45	45	56	56	36	37	42	42	46	46	52	52	47	47	55	54	47	46	49	48	48	49	52	52	56	56	51	50	50	50	51	51	54	54	55	56	51	51	45	45
47	47	58	58	38	39	44	44	48	48	54	53	49	49	57	56	49	48	51	50	50	50	54	54	57	58	52	52	52	52	53	53	56	55	57	57	53	53	47	47
49	49	60	59	40	41	46	46	50	50	56	55	51	51	59	58	51	50	53	52	52	52	56	56	59	60	54	54	54	54	55	55	57	57	59	59	55	55	49	49
50	50	61	61	42	43	48	49	52	52	57	57	53	53	60	60	53	53	55	54	53	54	58	57	61	61	56	56	56	55	57	56	59	59	60	61	56	56	51	51
52	52	63	62	44	45	51	51	54	54	59	59	55	55	62	61	55	55	57	56	55	56	59	59	62	63	57	57	57	57	58	58	61	61	62	62	58	58	52	52
54	54	64	64	46	47	53	53	56	56	61	61	57	57	64	63	57	56	59	57	57	58	61	61	64	64	59	59	59	59	60	60	62	62	64	64	60	60	54	54
56	56	66	66	48	49	55	55	58	58	63	63	59	59	66	65	59	59	61	59	59	60	63	63	66	66	61	60	61	60	62	62	64	64	65	65	61	61	56	56
58	58	67	67	50	50	57	57	59	60	64	64	60	60	67	66	61	60	62	61	60	61	64	64	67	67	62	62	62	62	63	63	65	65	66	67	63	63	57	57
59	59	**69**	68	**52**	52	**59**	59	**61**	61	**66**	66	**62**	62	**69**	68	**62**	62	**64**	63	**62**	63	**66**	66	**69**	69	**64**	63	**64**	64	**65**	65	**67**	67	**68**	68	**64**	64	**59**	59
61	61	70	69	53	54	60	60	63	63	67	67	64	64	70	69	64	64	65	64	64	64	67	67	70	70	65	65	65	65	66	66	68	68	69	69	66	66	60	61
62	62	71	71	55	56	62	62	64	65	69	69	65	65	72	71	66	65	67	66	65	66	69	69	71	71	66	66	66	66	67	67	70	69	70	71	67	67	62	62
64	64	72	72	57	57	64	64	66	66	70	70	67	67	73	72	67	67	69	67	67	67	70	70	72	73	68	68	68	68	69	69	71	71	72	72	68	68	63	63
65	65	74	73	58	59	65	65	67	67	72	71	68	68	74	73	69	68	70	69	68	69	71	71	74	74	69	69	69	69	70	70	72	72	73	73	70	70	65	65
67	67	75	74	60	60	67	67	68	68	73	72	70	69	75	75	70	70	71	70	69	70	73	72	75	75	70	70	70	70	71	71	73	73	74	74	71	71	66	66
68	68	76	75	61	62	68	68	69	70	74	74	71	70	76	76	71	71	72	71	70	71	74	73	76	76	71	71	71	71	72	72	74	74	75	75	72	72	67	67
69	69	77	76	63	63	69	69	71	71	75	75	72	72	77	77	72	72	73	72	72	72	75	74	77	77	72	72	72	72	73	73	75	75	76	76	73	73	68	68
70	70	78	77	64	64	70	70	72	72	76	76	73	73	78	78	73	73	74	74	73	73	76	76	78	78	73	73	73	73	74	74	76	76	77	77	74	74	69	69
72	71	79	78	65	66	72	72	73	73	77	77	74	74	79	79	75	74	76	75	74	74	77	77	79	79	75	74	74	74	76	76	77	77	78	78	75	75	71	71
73	73	80	79	66	67	73	73	74	74	78	78	75	75	80	79	76	75	77	76	75	75	78	77	79	80	75	75	75	75	77	77	78	78	79	79	76	76	72	72
74	74	80	80	68	68	74	74	75	75	79	79	76	76	81	80	77	76	78	77	76	76	78	78	80	80	76	76	76	76	77	77	79	79	79	80	77	77	73	73
75	75	81	81	69	69	75	75	76	76	79	79	77	77	82	81	77	77	78	78	77	77	79	79	81	81	77	77	77	77	78	78	80	80	80	80	78	78	73	74
76	76	82	82	70	71	76	76	76	77	80	80	78	78	82	82	78	78	79	79	78	78	80	80	82	82	78	78	78	78	79	79	81	81	81	81	79	78	74	75
76	76	83	82	71	71	76	76	77	77	81	81	79	78	83	82	79	79	80	79	78	79	81	81	82	82	79	78	79	79	80	80	81	81	81	82	79	79	75	75
77	77	83	83	72	73	77	77	78	78	82	82	80	79	84	83	80	80	81	80	79	80	81	81	83	83	79	79	79	79	81	81	82	82	82	82	80	80	76	76
78	78	84	84	73	74	78	78	79	79	82	82	80	80	84	84	81	80	82	81	80	80	82	82	84	84	80	80	80	80	81	81	83	83	83	83	81	81	77	77
79	79	85	84	74	75	79	79	80	80	83	83	81	81	85	85	82	81	82	82	81	81	83	83	84	84	81	81	81	81	82	82	83	83	84	84	82	81	78	78
80	80	86	85	75	76	80	80	80	81	84	84	82	82	86	85	82	82	83	82	82	82	84	84	85	85	82	82	82	82	83	83	84	84	84	85	82	82	79	79
81	81	86	86	76	77	81	81	81	82	85	85	83	83	87	86	83	83	84	83	83	83	84	84	86	86	83	83	83	83	84	84	85	85	85	85	83	83	80	80
82	82	87	86	77	78	81	81	82	82	85	85	84	83	87	86	84	84	85	84	83	84	85	85	86	86	83	83	83	83	84	84	86	86	86	86	84	84	80	81
83	82	87	87	78	79	82	82	83	83	86	86	84	84	88	87	85	84	85	85	84	84	86	85	87	87	84	84	84	84	85	85	86	86	86	87	85	85	81	82
83	83	88	87	79	79	83	83	83	84	87	86	85	85	88	88	85	85	86	85	85	85	86	86	87	88	85	85	85	85	86	86	87	87	87	87	86	85	82	83
84	84	88	88	80	80	84	83	84	84	87	87	86	85	89	88	86	86	87	86	85	86	87	87	88	88	86	85	85	85	87	87	88	88	88	88	86	86	83	83

4. Pollen count data for core TB07-1

Depth (cm)	Age (cal BP)	Salix	Betula	Picea	Larix	Pinus	Abies	Alnus	Fraxinus nigra	Populus	Ostrya	Quercus	Ulmus	Tsuga	Nyssa	Acer	F. pennsylvanica	Juglans
10	-43		13	10		10			5		2	77					2	6
20	-26		32	15		11			1			85		3		3	1	1
30	-5		30	7	4	10						69		3		1		1
40	22		46	7	3	4		4	2			45		4			2	1
50	54		18	11	3	7			5			57		3		4	5	
60	91		24	25	2	11						72		18				3
70	132		17	22	1	6						66		14				
80	178		24	13		10						62		21		2		2
90	229		18	9		29						53		28		26		
100	284		15	10		17			2			72		21		30	3	
110	343		20	9	4	26			5			73		18		12	5	
120	406		37	19		13		1				102		16		2		
130	474		34	23		9			6			100	3	15		3	9	6
140	545	4	23	14	3	8		1	2			86		16			4	
150	621	5	26	26					1			92		14			3	
160	700		17	29		1		2	6		4	76	4	12		1	6	
170	783	3	20	20		23	1	2	9		5	78	1	21			9	1
180	870		24	15		13	4		12		2	114		15		3	6	
190	960		68	16		15	5		7		1	51	3	8		5	5	
200	1054		18	18		29		4				67		18		6	7	
210	1150		42	19		25	1	2	1			104	13	20		3	3	
220	1251	10	25	7		32			0		3	74	14	10			1	
230	1354		34	13		42	1		1			88	8	18		11	3	
240	1460		23	21		12		2	0			96		17		1	3	
250	1570		21	14		22		8	1			95		29			3	
260	1682		21	9		41		6	1			88		29			3	
270	1797		26	7		25			2			104		27			3	
280	1914	6	25	8		24		7	1		1	85		18			3	
290	2034		29	7		40		3	1			107		18			3	
300	2157		18	18		17		1	0			90		23			3	
340	2669	6	24	8		36		3	0			90		20			3	
360	2938	2	20	5		32	6	8	4			122	6	6			2	
380	3213	1	26	1		50		7			1	107	2	5		4	7	
400	3495		10			38		19	1			121	2	4		2	7	
420	3782		24	5		24	1	7	3		1	115	4	1			5	
440	4074		20	3		41		6	1		2	116	2			4	13	1
460	4369		23	3		22		15	1		2	112	2			3	8	
480	4668		25	11		28	2	11	4		2	127	3	5		3	3	
500	4969		19	1		13		7	1		1	133	1	6		1	1	
520	5272		27	1		11		11	6			141		19		5	1	
540	5575		10			13		9	2			111	4	48		4	3	
560	5878		8			2		5	4			135	3	37		1		
580	6181		11			7		15	1			139		38			10	
600	6482		16			6		7	1			107	1	36		7	4	
620	6780		20			4		7				120	4	41		8	6	2
640	7075	5	12			13		8				110	3	27	1	2	8	1
660	7366	6	13			10		4	1			125	1	18		1	3	1
680	7653		14			9		6	4		1	109	3	33		4	6	1
700	7934		25			11		8	1			115	4	27		7	7	1
720	8208		18			16		1	4			110		26		4	3	
740	8475		19			15		4	3			119	2	18		4		1
760	8735	1	7			22		4	1			127		18		5	8	
780	8985	1	20			15		4	3			127		21			7	
800	9227		12			24		3	5	1		130	5	13		2	2	
820	9458	2	14			30	3	6	5			131	2	12		5	1	
840	9677		10			40	3	14	5		1	132	3	11		3		1
860	9885		11	7		51	6	5				132	4	13			8	
880	10081		12	6		58	2	7	6			99		10		1		1
900	10263		11	3		64	8	3	2			100	5	13		1	2	
920	10430		9	2		65		5	8		3	106	8	15		2		
940	10583		15	4		95	7	3	8			56	2	30		1	1	
960	10720		4	10		98		1	8			71	8	60		6		
980	10840		18	12		104		3	6			93	3	13		1	1	4
1000	10943		8	7		145	1	3	6		1	47	3	13		2		
1020	11028		10	0		172		2				35	3	3		5	4	
1040	11094		47	5		166		9	5	1		16	1	7		3	1	
1060	11140		90	19		105	4	32	3			8		10				

Fagus	Carya	Tilia	Castanea	Ericaceae	Ilex	Vaccinium	Rubus	Cyperaceae	Artemisia	Urtica	Chenopodiaceae	Helianthus	Drosera	Arceuthobium	Poaceae	Ambrosia
	4			4											1	12
1	7			27							1					19
1	6			29							4					35
	10			9												41
		1	7	9							3				2	78
4	2		7					9								63
12	6		7	2				13			3					36
11	7										2					18
6	3		1													3
3	8		5	4												6
13	13		1	2												3
26	8	8														1
12	6	2	3	3											4	
12	7		8	4								1			14	1
10	2		2	2											17	3
23	7		1									1			11	
5	8	3		4								5	1			1
	6	5		3								5				5
2	13	4	2	9												19
9	22			3							7	1				16
6	15	3		4								1				3
4	9			2		3										
3	9	5		1							2					3
6	8	1	3													
5	12														2	
2	11	2		1												
11	9		1	4											3	
6	18															3
5	12		1	1		1					1			3		
9	17			3												2
6	12			3										2		
9	9										1					
3	7														1	
16	14										1					2
8	3		1	2							1					2
16	8			1							2					
13	7		2													1
15	12															1
12	11		7									1				
9	7		6									1				2
8	15		4								1					
8	8										1					
14	10		3	2												
10	2										1	1				4
12	4															
22	4										2				1	
9	2															
10	1										1	1				
15	1	1			1							1			2	2
6	1			1			1									
9															1	2
3	1															4
10			2													3
7	1								2							
4							1				1					2
1	2										1					
5															1	4
3								4		2	1	1			1	2
6								1			1				1	1
5					1										3	
3									2							
									1							
6					1											
13															1	
	1							1	4							1
	1											2				
				1				2	1							

Pteridium	Dryopteris	Osmunda	Sphagnum	Sparganium	Myriophyllum	Nymphaeaceae	Brasenia	Nuphar	Cephalanthus	Iva	Lemna	Sagittaria	Sium	Equisetum	Indeterminable	Total Pollen Sum	Lycopodium
3																126	45
3															13	176	23
			3												12	174	35
	1		3												4	130	39
			7												14	202	37
	9		28												27	253	45
			17												13	195	24
			37			25									9	206	21
			1									1			19	170	19
															13	184	22
			1												19	191	18
	1		1												14	193	17
	1		2					6								190	18
															8	172	15
															6	152	9
																155	13
			7											1	4	189	12
														2	3	198	21
			5													154	30
			2					2				1			4	198	19
			1												6	211	25
	2		11												4	169	18
															3	198	20
1			3					1							10	164	9
			2					1							12	192	5
			2												11	197	12
			1					2							10	202	21
1								1							7	175	8
								1							9	206	14
								1							10	176	11
			5			1									9	190	2
1	5	1					4	1							5	222	7
2	1		1				2									200	5
1	3	3	1												4	239	10
7	3	3									1				7	199	7
		1	1												9	224	8
	2	4	2				2	2			2				4	206	13
1	2	7					6								2	234	6
	1	2					1								4	203	9
	3		2				1						1		6	232	18
	1														7	230	12
	2		1												5	212	15
1	2						1				1				5	249	20
3	3		1				2							6	4	206	2
3	4	1					2							5	3	226	5
	2		1				2							8	4	219	8
	2			3			1		1					10	4	196	3
1	4						3		2	1				25	2	227	9
							1							16	2	223	4
	5		2				1							13	3	197	3
	10			1			1							4	2	196	4
	5		2						1					10	3	214	4
2	2							1			2			9	4	212	3
	4								1					8	6	214	3
	1								1		1			7	2	215	5
1	1										1			12	5	237	6
5	4											2		12	2	254	5
6	1		2		1			1			1			7	1	218	6
5	1		1				1	1			2			10	5	234	8
6	3	2												15	3	250	5
8	1							2						21	1	241	3
5	7		2					1			2			23	2	295	6
1	1	1												14	1	253	2
4	3				2									20		264	5
2									1					12		246	2
5	3													10	5	235	4
3			1						1	1	1				1	174	4

5. Testate amoebae count data for core TB07-1

Depth (cm)	Age (cal BP)	Amphitrema flavum	A. wrightianum	Arcella artocrea type	A. catinus	A. discoides type	Assulina muscorum/seminulum	Bulinularia indica	Centropyxis aculeata type	C. cassis type	C. platystoma type	Corythion-Trinema type	Cyclopyxis-Phryganella type	Difflugia pulex	D. oblonga	Euglypha spp.	Heleopera spp.	Hyalosphenia elegans	H. papilio	H. subflava	Nebela carinata/marginata	N. flebellulum	N. griseola	N. militaris	N. tincta	Pseudodifflugia fascicularis	Trigonopyxis arcula	Indeterminable	Total	Lycopodium
10	-43	3	0	0	0	6	8	0	12	0	0	11	25	0		15	2	10	13	18	0	0	3	42	0	8	0	0	176	45
20	-26	1	0	0	1	28	14	0	7	0	1	1	7	35		12	11	19	10	33	0	12	0	59	0	0	5	0	256	23
30	-5	0	0	0	0	34	3	0	12	0	0	6	21	48		5	13	14	10	51	0	7	0	35	0	0	4	0	263	35
40	22	0	0	0	9	15	12	0	22	3	4		23			5	18	16	20	45				25	4		8		229	39
50	54	23		15		2	18		8	28	1		30	1		1	8	10	23	43			2	13			14	4	244	37
60	91	21		4		2	7		43							1	4	18	40	2			2	10				6	160	45
70	132	11	17		10		9		30					1		3	25	6	30	3	15		1	1				10	172	24
80	178	5	4	11	3	8	9		34	5	4		3			3	23		18	23				8			4	8	173	21
90	229	0				5			7								4		2				1				4	3	26	72
100	284	2				1			28					1			7			1								4	44	124
110	343	4			1	3			41											1								7	57	60
120	406	3			8				42				1			1	2		1									2	60	25
130	474	1		2		5			3											1									12	18
140	545	6	1		2	2	4		14								4	8	9					4		3		1	58	25
150	621	10		1	3		3	1	21				4				3	2	1	1				1		2		3	56	15
160	700	17			9	1	3	2	22				1	1			5	1	4								1		67	19
170	783	3	5		3		3		37		2		2	4			5	8	7	3				9				7	98	15
180	870				6		1		37		1						3		1	1							1	2	53	35
190	960	3	2	1	4	3	7		26		2		8			3	6	2	8	25				20		10	5	4	139	30
200	1054	3	4	4		11	7		20		6		3	8		1	7	12	8	16			2	33	2		4	9	160	35
210	1150	1			1		1		11								1	1	2	1									19	18
220	1251	1			1	1			35		5					2	2			2								3	52	16
230	1354	1			3	2	1		34	1			1	2		1	3		3										52	39
240	1460					5	1		25								1						5			3		4	44	11
250	1570					16			30			2	1				1						2						52	15
260	1682					2			46	3																			51	37
270	1797					8			40						2													1	51	38
280	1914				1	5			38					1									5						50	20
290	2034				1	6			40					2	2								1						52	30
300	2157			2			1	1	6				4				4	2	1										21	11
340	2669								22						5		3						4						34	24

6. Diatom count data for core TB07-1

Depth (cm)	Age (cal BP)	Diatom	Lycopodium
10	-43	0	45
20	-26	0	23
30	-5	0	35
40	22	0	39
50	54	0	37
60	91	0	45
70	132	0	24
80	178	0	21
90	229	38	19
100	284	26	22
110	343	18	18
120	406	0	17
130	474	0	18
140	545	3	15
150	621	3	9
160	700	0	13
170	783	0	12
180	870	0	21
190	960	0	30
200	1054	3	19
210	1150	0	25
220	1251	0	18
230	1354	0	20
240	1460	133	9
250	1570	565	5
260	1682	781	12
270	1797	752	21
280	1914	1634	8
290	2034	685	14
300	2157	539	11
340	2669	85	2

Vita

Personal Information

Born: December 9th, 1979, Beijing, China

Parents: Cai, Jiming (Father) Zhang, Jing (Mother)

Education

Lehigh University, Bethlehem PA

M.S. Earth and Environmental Sciences, September 2008

University of Saskatchewan, Saskatoon, SK

M.S. Physical Geography, April 2006

Peking University, Beijing, China

B.S. Natural Resource & Environmental Ecology, July 2002

Research Experience

Department of Earth and Environmental Sciences, Lehigh University, Bethlehem, PA

Teaching Assistant of an undergraduate course "earth system science", January 2008 – May 2008;

Research Assistant, January 2007 – June 2008;

Teaching Assistant of an undergraduate course "environmental geology", September 2006 – December 2006.

Department of Geography, University of Saskatchewan, Saskatoon, SK

Teaching Assistant of course "physical geography" and "quantitative geography", September 2003 – December 2005.

Conferences Attended

April 15th – 19th, 2008 Association of American Geographers, Boston, MA. Paper: a temperate poor fen as a carbon sink under warm climate during the Holocene.

June 19th - 25th, 2005 North America Paleontology Convention, Dalhousie University, Halifax, Nova Scotia, Canada. Poster: Taphonomy and paleoecology of glaciomarine molluscan faunas, Axel Heiberg Island, Nunavut.

October 1st - 2nd, 2004 Annual Meeting the Prairie Division of the Canadian Association of Geographers, St. Peter's College, Muenster, Saskatchewan, Canada.

Professional Affiliations

Member of The American Association of Geographers, 2007- present

Member of the Canadian Association of Geographers, 2003 – 2006

END OF TITLE